CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses and results in support of the information presented in the notice of proposed rulemaking (NOPR) for commercial refrigeration equipment (CRE). This NOPR TSD also complements the life-cycle cost (LCC) and payback period (PBP), and national impact analysis (NIA) spreadsheets that are posted on the U.S. Department of Energy's (DOE's) website at: www1.eere.energy.gov/buildings/appliance_standards/rulemaking.aspx/ruleid/27.

1.2 SUMMARY OF NATIONAL BENEFITS

DOE's analyses indicate that the proposed standards would save a significant amount of energy. The lifetime savings for commercial refrigeration equipment purchased in the 30-year period that begins in the year of the compliance with amended standards (2017–2046) amount to 1.001 quadrillion British thermal units (quads). This is equivalent to 83 percent of total U.S. commercial sector energy (source energy) used for refrigeration in 2010.[a]

The cumulative national net present value (NPV) of total customer costs and savings of the proposed standards for commercial refrigeration equipment in 2012$ ranges from $1.606 billion (at a 7 percent discount rate) to $4.067 billion (at a 3 percent discount rate). This NPV expresses the estimated total value of future operating cost savings minus the estimated increased installed costs for equipment purchased in 2017–2046, discounted to 2013. The industry net present value (INPV) is the sum of the discounted cash flows to the industry from the base year (2013) through the end of the analysis period (2046). Using a real discount rate of 10 percent,[b] DOE estimates that the INPV for manufacturers of commercial refrigeration equipment is $1,162.0 million in 2012$. Under the proposed standards, DOE expects that manufacturers may lose up to 7.97 percent of their INPV, or approximately $92.6 million.

The proposed standards are expected to have significant environmental benefits. The energy savings would result in cumulative greenhouse gas (GHG) emission reductions of 54.88 million metric tons (MMt)[c] of carbon dioxide (CO_2), 265.9 thousand tons of methane, 1.1 thousand tons of nitrous oxide, 70.1 thousand tons of sulfur dioxide (SO_2), 81.1 thousand tons of NOx, and 0.1 tons of mercury (Hg).[d] DOE estimates that the net present monetary value of the CO_2 emissions reduction would be between $0.31 and $4.55 billion. DOE also estimates the

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[a] Total U.S. commercial sector energy (source energy) used for refrigeration in 2010 was 1.21 quads. Source: U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy. Buildings Energy Data Book, Table 3.1.4, 2010 Commercial Energy End-Use Splits, by Fuel Type (Quadrillion Btu). 2012. (Last accessed April 23, 2013.)
http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=3.1.4

[b] This is the rate used to discount future cash flows in the Manufacturer Impact Analysis. A discount rate of 10 percent was calculated based on SEC filings and feedback from manufacturer interviews about the current cost of capital in the industry. For more information, refer to Chapter 12 of the NOPR TSD.

[c] A metric ton is equivalent to 1.1 U.S. short tons. Results for NO_x and Hg are presented in short tons.

[d] DOE calculated emissions reductions relative to the *Annual Energy Outlook* 2013 (*AEO2013*) Reference case, which generally represents current legislation and environmental regulations for which implementing regulations were available as of December 31, 2012.

present monetary value of the NO_x emissions reduction would be between $8.8 and $90.7 million at a 7 percent discount rate and between $19.1 and $196.2 million at a 3 percent discount rate.[e]

The benefits and costs of today's proposed standards, for commercial refrigeration equipment sold in 2017–2046, can also be expressed in terms of annualized values. The annualized monetary values are the sum of 1) the annualized national economic value of the benefits from the customer operation of equipment that meets the proposed standards (consisting primarily of operating cost savings from using less energy, minus increases in equipment installed cost, which is another way of representing customer NPV) and 2) the annualized monetary value of the benefits of emission reductions, including CO_2 emission reductions.[f] The value of the CO_2 reductions is calculated using a range of values per metric ton of CO_2 (otherwise known as the Social Cost of Carbon [SCC]) developed by a recent Federal interagency process. The monetary costs and benefits of cumulative emissions reductions are reported in 2012$ to permit straightforward comparisons with the other costs and benefits. The derivation of the values of the SCC is discussed in appendices 14A and 14B.

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. customer 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 over the lifetimes of commercial refrigeration equipment shipped in 2017–2046. The SCC values, on the other hand, reflect the present value of some future climate-related impacts resulting from the emission of 1 ton of CO_2 in each year. These impacts continue well beyond 2100.

Table 1.2.1 shows the annualized benefits and costs of the proposed standards. The results of the primary estimate are as follows. Table 1.2.1 shows the primary, low net benefits, and high net benefits scenarios. The primary estimate is the estimate in which the operating cost savings were calculated using the *Annual Energy Outlook 2013* (*AEO2013*)[1] Reference Case forecast of future electricity prices. The other two estimates, low net benefits estimate and high net benefits estimate, are based on the low and high electricity price scenarios from the *AEO2013* forecast. At a 7-percent discount rate for benefits and costs, the cost in the primary estimate of the standards proposed in today's notice is $82 million per year in increased equipment costs. The annualized benefits are $203 million per year in reduced equipment operating costs, $75 million in CO_2 reductions (note that DOE used a 3-percent discount rate, along with the corresponding SCC series that uses a 3-percent discount rate, to calculate the monetized value of

[e] DOE is currently investigating valuation of avoided Hg and SO_2 emissions.

[f] 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 2013, the year used for discounting the NPV of total consumer costs and savings, for the time-series of costs and benefits using discount rates of 3 and 7 percent for all costs and benefits except for the value of CO_2 reductions. For the latter, DOE used a range of discount rates, as shown in Table 1.2.1. From the present value, DOE then calculated the fixed annual payment over a 30-year period (2017 through 2046) that yields the same present value. The fixed annual payment is the annualized value. Although DOE calculated annualized values, this does not imply that the time-series of cost and benefits from which the annualized values were determined is a steady stream of payments.

CO_2 emissions reductions), and $3.75 million in reduced NO_x emissions. In this case, the annualized net benefit amounts to $199 million. At a 3-percent discount rate for all benefits and costs, the cost in the primary estimate of the amended standards proposed in today's notice is $97 million per year in increased equipment costs. The benefits are $299 million per year in reduced operating costs, $75 million in CO_2 reductions, and $5.33 million in reduced NO_x emissions. In this case, the net benefit amounts to $281 million per year.

Table 1.2.1 Annualized Benefits and Costs of Proposed Standards for Commercial Refrigeration Equipment

	Discount Rate	Primary Estimate* *million 2012$*	Low Net Benefits Estimate* *million 2012$*	High Net Benefits Estimate* *million 2012$*
Benefits				
Operating Cost Savings	7%	203	197	212
	3%	299	288	314
CO_2 Reduction Monetized Value (at $12.9/Metric Ton)**	5%	19	19	19
CO_2 Reduction Monetized Value (at $40.8/Metric Ton)**	3%	75	75	75
CO_2 Reduction Monetized Value (at $62.2/Metric Ton)**	2.5%	114	114	114
CO_2 Reduction Monetized Value (at $117.0/Metric Ton)**	3%	225	225	225
NO_x Reduction Monetized Value (at $2,639/Ton)**	7%	3.75	3.75	3.75
	3%	5.33	5.33	5.33
Total Benefits (Operating Cost Savings, CO_2 Reduction and NO_x Reduction)†	7%	281	275	290
	3%	379	368	394
Costs				
Total Incremental Installed Costs	7%	82	84	80
	3%	97	100	95
Net Benefits Less Costs				
Total Benefits Less Incremental Costs	7%	199	191	210
	3%	281	268	299

* This table presents the annualized costs and benefits associated with equipment shipped in 2017−2046. These results include benefits to consumers which accrue after 2046 from the products purchased in 2017−2046. The primary, low, and high estimates utilize forecasts of energy prices from the *AEO2013* Reference Case, Low Economic Growth Case, and High Economic Growth Case, respectively. In addition, incremental equipment costs reflect a medium decline rate for projected product price trends in the Primary Estimate, a low decline rate for projected equipment price trends in the Low Benefits Estimate, and a high decline rate for projected equipment price trends in the High Benefits Estimate. The methods used to derive projected price trends are explained in Appendix 10B.
** The interagency group selected four sets of SCC values for use in regulatory analyses. Three sets of values are based on the average SCC from the three integrated assessment models at discount rates of 2.5, 3, and 5 percent. The fourth set, 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 in parentheses represent the SCC in 2015. The SCC time series incorporate an escalation factor. The value for NO_X is the average of the low and high values used in DOE's analysis.
† Total Benefits for both the 3- and 7-percent cases are derived using the series corresponding to average SCC with 3-percent discount rate. In the rows labeled "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_X benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

DOE also calculated the low net benefits and high net benefits estimates by calculating the operating cost savings and incremental installed costs at the *AEO2013* low economic growth case and high economic growth case scenarios, respectively. These scenarios do not change the monetized emissions reductions values. The net benefits and costs for low and high net benefits estimates were calculated in the same manner as the primary estimate by using the corresponding values of operating cost savings and incremental installed costs.

1.3 OVERVIEW OF APPLIANCE STANDARDS

Part B of Title III of the Energy Policy and Conservation Act of 1975 (EPCA or the Act), Pub. L. 94-163, as amended by the National Energy Conservation Policy Act of 1978 (NECPA), Pub. L. 95-619; the National Appliance Energy Conservation Act of 1987 (NAECA), Pub. L. 100-12; the National Appliance Energy Conservation Amendments of 1988 (NAECA 1988), Pub. L. 100-357; and the Energy Policy Act of 1992 (EPACT 1992), Pub. L. 102-486, established the Energy Conservation Program for Consumer Products other than Automobiles. (42 U.S.C. 6291–6309) Part 3 of Title IV of NECPA amended EPCA to add Part A-1 of Title III, which established an energy conservation program for certain industrial equipment.[g] (42 U.S.C. 6311–6317) EPACT 1992 included amendments to EPCA that expanded Title III to include additional commercial equipment. The Energy Policy and Conservation Act of 2005 (EPACT 2005), Pub. L. 109-58, updated several existing standards and test procedures; prescribed definitions, standards, and test procedures for certain new consumer products and commercial equipment; and mandated that the Secretary of Energy (the Secretary) commence rulemakings to develop test procedures and standards for certain new consumer products and commercial equipment.

DOE is required to design each standard for this equipment to 1) achieve the maximum improvement in energy efficiency that is technologically feasible and economically justified and 2) result in significant conservation of energy. (42 U.S.C. 6295(o)(2)(A) and (o)(3)(B), 42 U.S.C. 6316(e)(1)(A)) To determine whether a proposed standard is economically justified, DOE will, after receiving comments on the proposed standard, determine whether the benefits of the standard exceed its burdens to the greatest extent practicable, considering the following seven factors:

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

2. the savings in operating costs throughout the estimated average life of the covered product in the type (or class) compared to any increase in the price of, or in the initial charges for maintenance expenses of, the covered products that are likely to result from the imposition of the standard;

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 covered products likely to result from the imposition of the standard;

[g] This part was originally titled Part C. However, it was redesignated Part A-1 after Part B of Title III of EPCA was repealed by Pub. L. 109-58.

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.

(See 42 U.S.C. 6295(o)(2)(B)(i); 6316(e)(1)(A))

For commercial refrigeration equipment, DOE is applying those factors in a manner consistent with its other energy conservation standards rulemakings to ascertain the maximum improvement in energy efficiency that is technologically feasible and economically justified for this equipment.

1.4 OVERVIEW OF COMMERCIAL REFRIGERATION EQUIPMENT STANDARDS

EPACT 2005 included amendments to EPCA that update several existing standards and test procedures; prescribe definitions, standards, and test procedures for certain new consumer products and commercial equipment; and mandate that DOE commence rulemakings to develop test procedures and standards for certain new consumer products and commercial equipment. With respect to the standards for commercial refrigeration equipment, EPCA, as amended by EPACT 2005, also stated that:

> (A) Not later than January 1, 2013, the Secretary shall issue a final rule to determine whether the standards established under this subsection should be amended.
>
> (B) Not later than 3 years after the effective date of any amended standards under subparagraph (A) or the publication of a final rule determining that the standards should not be amended, the Secretary shall issue a final rule to determine whether the standards established under this subsection or the amended standards, as applicable, should be amended.
>
> (C) If the Secretary issues a final rule under subparagraph (A) or (B) establishing amended standards, the final rule shall provide that the amended standards apply to products manufactured on or after the date that is –
>
> (i) 3 years after the date on which the final amended standard is published; or
>
> (ii) if the Secretary determines, by rule, that 3 years is inadequate, not later than 5 years after the date on which the final rule is published.

42 U.S.C. 6313(c)(6)

1.4.1 Definitions

Section 136(a)(3) of EPACT 2005 amended section 340 of EPCA by striking paragraph 9 and inserting definitions for the following terms that describe commercial refrigeration equipment:

> (9)(A) The term "commercial refrigerator, freezer, and refrigerator-freezer" means refrigeration equipment that—
>
> (i) is not a consumer product (as defined in section 321 of EPCA);
>
> (ii) is not designed and marketed exclusively for medical, scientific, or research purposes;
>
> (iii) operates at a chilled, frozen, combination chilled and frozen, or variable temperature;
>
> (iv) displays or stores merchandise and other perishable materials horizontally, semi-vertically, or vertically;
>
> (v) has transparent or solid doors, sliding or hinged doors, a combination of hinged, sliding, transparent, or solid doors, or no doors;
>
> (vi) is designed for pull-down temperature applications or holding temperature applications; and
>
> (vii) is connected to a self-contained condensing unit or to a remote condensing unit.
>
> (B) The term "holding temperature application" means a use of commercial refrigeration equipment other than a pull-down temperature application, except a blast chiller or freezer.
>
> * * *
>
> (D) The term "pull-down temperature application" means a commercial refrigerator with doors that, when fully loaded with 12 ounce beverage cans at 90 degrees F, can cool those beverages to an average stable temperature of 38 degrees F in 12 hours or less.
>
> (E) The term "remote condensing unit" means a factory-made assembly of refrigerating components designed to compress and liquefy a specific refrigerant that is remotely located from the refrigerated equipment and consists of one or more refrigerant compressors, refrigerant condensers, condenser fans and motors, and factory supplied accessories.
>
> (F) The term "self-contained condensing unit" means a factory-made assembly of refrigerating components designed to compress and liquefy a specific refrigerant

that is an integral part of the refrigerated equipment and consists of one or more refrigerant compressors, refrigerant condensers, condenser fans and motors, and factory supplied accessories.

42 U.S.C. 6311(9)

1.4.2 Rulemaking History

The current standards for commercial refrigeration equipment are a result of two legislative actions and one rulemaking: standards prescribed by EPACT 2005 for certain equipment, standards for other equipment established by DOE through issuance of a final rule, and standard prescribed by American Energy Manufacturing Technical Corrections Act (AEMTCA), Pub. L. 112-210 (2012).

1.4.2.1 Standards Prescribed by Statute

Section 136(c) of EPACT 2005 amended EPCA to prescribe energy conservation standards for self-contained equipment consisting of commercial refrigerators with solid doors, commercial refrigerators with transparent doors, commercial freezers with solid doors, commercial freezers with transparent doors, commercial refrigerator/freezers with solid doors designed for holding temperature applications, and commercial refrigerators with transparent doors designed for pull-down temperature applications. (42 U.S.C. 6313(c)(1–3)) These standards became effective on January 1, 2010. See Table 1.4.1 in section 1.4.3.

Section 4 of AEMTCA established a new standard for self-contained service over counter commercial refrigerators for medium temperature applications (SOC.SC.M) by amending section 342(c) of EPCA. (42 U.S.C. 6313(c)(4)) SOC.SC.M equipment had previously been inadvertently classified by EPACT 2005 under the category self-contained commercial refrigerators with transparent doors. (42 U.S.C. 6313(c)(2)) Section 4 of AEMTCA was aimed at addressing this discrepancy.

1.4.2.2 Standards Established by Rulemaking

Section 136(c) of EPACT 2005 also amended EPCA to mandate that DOE set standards for the following additional categories of equipment: ice-cream freezers; self-contained commercial refrigerators, freezers, and refrigerator-freezers without doors; and remote condensing commercial refrigerators, freezers, and refrigerator-freezers. (42 U.S.C. 6313(c)(5)(A)) DOE undertook a rulemaking process beginning in April 2006, when it published the *Rulemaking Framework for Commercial Refrigeration Equipment Including Ice-Cream Freezers; Self-Contained Commercial Refrigerators, Freezers, and Refrigerator-Freezers without doors; and Remote Condensing Commercial Refrigerators, Freezers, and Refrigerator-Freezers* (April 2006 framework document). The April 2006 framework document described the procedural and analytical approaches DOE anticipated using to evaluate the establishment of energy conservation standards for these types of commercial refrigeration equipment. This document is available at www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/comml_refrig_framework.pdf

DOE held a public meeting on May 16, 2006 to discuss procedural and analytical approaches to the rulemaking and to inform and facilitate the involvement of interested parties in the rulemaking process. The analytical framework presented at the public meeting described different analyses, such as the engineering analysis and the LCC and PBP analyses, the methods proposed for conducting them, and the relationships among the various analyses.

After the public meeting associated with the April 2006 framework document, as part of the information gathering and sharing process for the preliminary manufacturer impact analysis (MIA), DOE conducted interviews with CRE manufacturers. DOE selected companies that represented production of all types of equipment covered by the rulemaking, ranging from small to large manufacturers, and included Air-Conditioning and Refrigeration Institute (ARI)[h] member companies and non-ARI member companies. DOE had four objectives for these interviews: 1) solicit feedback on the draft engineering analysis (including methodology, production costs, manufacturing processes, and findings); 2) solicit feedback on topics related to the preliminary MIA; 3) provide an opportunity, early in the rulemaking process, for these manufacturers to express specific concerns to DOE; and 4) foster cooperation between the manufacturers and DOE.

DOE developed a preliminary engineering analysis to estimate the cost of manufacturing equipment at efficiencies above the baseline levels. DOE also developed spreadsheets to conduct the LCC, PBP, and NIA. The LCC spreadsheet calculates national distributions of LCC savings at various energy efficiency levels above the baseline. It can also provide LCC savings based on typical input values for several business types that use commercial refrigeration equipment. The NIA spreadsheet calculates the national energy savings (NES) and national NPVs at various energy efficiency levels. It also includes a model that forecasts shipments for the various equipment classes of commercial refrigeration equipment at different efficiency levels.

In July 2007, DOE published an advance notice of proposed rulemaking (July 2007 ANOPR) for commercial refrigeration equipment including ice-cream freezers; self-contained commercial refrigerators, freezers, and refrigerator-freezers without doors; and remote condensing commercial refrigerators, freezers, and refrigerator-freezers. 72 FR 41162 (July 26, 2007). In the July 2007 ANOPR analysis, DOE considered establishing energy conservation standards for these types of commercial refrigeration equipment and announced a public meeting to receive comments on a variety of issues. This document is available at www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/comml_refrig_anopr_072607.pdf.

DOE held a public meeting on August 23, 2007 (August 2007 ANOPR public meeting) to provide interested parties the opportunity to comment on the equipment classes proposed by DOE in the July 2007 ANOPR; the analytical framework, models, and tools (*e.g.*, LCC and NES spreadsheets) that DOE had developed to perform analyses of the impacts of potential energy conservation standards; the results of the preliminary analyses; and the candidate energy conservation standard levels.

[h] On January 1, 2008, the Air-Conditioning and Refrigeration Institute (ARI) and the Gas Appliance Manufacturers Association (GAMA) merged to become the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), to represent the interests of cooling, heating, and commercial refrigeration equipment manufacturers.

After the publication of the July 2007 ANOPR and the presentation of the ANOPR to interested parties at the August 2007 ANOPR public meeting, DOE conducted additional interviews with CRE manufacturers as part of its development of the MIA for the NOPR. There were 13 general topics discussed during each of the interviews: 1) general key issues; 2) company overview and organizational characteristics; 3) company financial parameters; 4) production cost breakdown; 5) shipment projections and market shares; 6) equipment mixes; 7) conversion costs; 8) markups and profitability; 9) cumulative regulatory burden; 10) exports, foreign competition, and outsourcing; 11) direct employment impact assessment; 12) market consolidation; and 13) baseline products and different design options.

Based on findings from the preliminary engineering, LCC and NIA, and public comments provided in response to the July 2007 ANOPR, DOE updated these analyses. In updating these analyses, DOE reviewed the recommendations made on April 21, 1998 by the Advisory Committee on Appliance Energy Efficiency Standards. (Advisory Committee, No. 96)[i] DOE's analysis implemented recommendations related to 1) defining a range of energy price futures for each fuel used in the economic analyses; and 2) defining a range of primary energy conversion factors and associated emission reductions based on the generation of energy and emissions that would be displaced by energy efficiency standards for each rulemaking. In addition, DOE performed additional analyses assessing impacts on national employment, consumer subgroups, utilities, and the environment. DOE also developed analysis of alternatives to efficiency standard regulations.

On August 25, 2008, DOE published a NOPR (August 2008 NOPR) for commercial refrigeration equipment including ice-cream freezers; self-contained commercial refrigerators, freezers, and refrigerator-freezers without doors; and remote condensing commercial refrigerators, freezers, and refrigerator-freezers, to propose energy conservation standards for these types of commercial refrigeration equipment, and to announce a public meeting to receive comments on a variety of issues. 73 FR at 50072. This document is available at www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/cre_nopr_fr_final.pdf.

DOE held a public meeting on September 23, 2008 (September 2008 public meeting) to provide interested parties the opportunity to comment on the proposed standards, results of the analyses, and the trial standard levels (TSLs).

After the publication of the August 2008 NOPR and the September 2008 NOPR public meeting, DOE received more than 100 comments from a diverse set of interested parties, including manufacturers and their representatives, trade associations, wholesalers and distributors, energy conservation advocates, and electric utilities. Comments addressed DOE methodology, the information DOE used in its analyses, results of and inferences drawn from the analyses, impacts of standards, the merits of the different TSLs, standards options DOE considered, and other issues affecting adoption of standards for commercial refrigeration equipment.

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[i] Advisory Committee, No. 96 refers to the recommendations of the Advisory Committee on Appliance Energy Efficiency Standards and is available for inspection at the U.S. Department of Energy, 950 L'Enfant Plaza SW., Suite 600, Washington, DC, 20024 (Resource Room) in the file under "Energy Conservation Program for Consumer Products: Procedures for Consideration of New or Revised Energy Conservation Standards for Consumer Products," RIN [1904–AA83], as document number 96.

DOE considered these comments in developing a final rule for commercial refrigeration equipment, published on January 9, 2009 (herein referred to as the "January 2009 final rule"). 74 FR at 1092. The January 2009 final rule established standards for ice-cream freezers; self-contained commercial refrigerators, freezers, and refrigerator-freezers without doors; and remote condensing commercial refrigerators, freezers, and refrigerator-freezers, which became effective on January 1, 2012.

1.4.3 Current Energy Conservation Standards

Table 1.4.1 and Table 1.4.2 show the current standards for the two subsets of commercial refrigeration equipment.

Table 1.4.1 CRE Standards Prescribed by EPCA, Effective January 1, 2010

Category	Maximum Daily Energy Consumption *kWh/day**
Refrigerators with solid doors	0.10 V + 2.04
Refrigerators with transparent doors	0.12 V + 3.34
Freezers with solid doors	0.40 V + 1.38
Freezers with transparent doors	0.75 V + 4.10
Refrigerators/freezers with solid doors	the greater of 0.27 AV - 0.71 or 0.70
Self-contained refrigerators with transparent doors designed for pull-down temperature applications	0.126 V + 3.51

* kilowatt-hours per day

Table 1.4.2 CRE Standards Established in the 2009 Final Rule, Effective January 1, 2012

Equipment Class*	Standard Level **,† *kWh/day*		Equipment Class	Standard Level **,† *kWh/day*
VOP.RC.M	0.82 × TDA + 4.07		VCT.RC.I	0.66 × TDA + 3.05
SVO.RC.M	0.83 × TDA + 3.18		HCT.RC.M	0.16 × TDA + 0.13
HZO.RC.M	0.35 × TDA + 2.88		HCT.RC.L	0.34 × TDA + 0.26
VOP.RC.L	2.27 × TDA + 6.85		HCT.RC.I	0.4 × TDA + 0.31
HZO.RC.L	0.57 × TDA + 6.88		VCS.RC.M	0.11 × V + 0.26
VCT.RC.M	0.22 × TDA + 1.95		VCS.RC.L	0.23 × V + 0.54
VCT.RC.L	0.56 × TDA + 2.61		VCS.RC.I	0.27 × V + 0.63
SOC.RC.M	0.51 × TDA + 0.11		HCS.RC.M	0.11 × V + 0.26
VOP.SC.M	1.74 × TDA + 4.71		HCS.RC.L	0.23 × V + 0.54
SVO.SC.M	1.73 × TDA + 4.59		HCS.RC.I	0.27 × V + 0.63
HZO.SC.M	0.77 × TDA + 5.55		SOC.RC.L	1.08 × TDA + 0.22
HZO.SC.L	1.92 × TDA + 7.08		SOC.RC.I	1.26 × TDA + 0.26
VCT.SC.I	0.67 × TDA + 3.29		VOP.SC.L	4.37 × TDA + 11.82
VCS.SC.I	0.38 × V + 0.88		VOP.SC.I	5.55 × TDA + 15.02
HCT.SC.I	0.56 × TDA + 0.43		SVO.SC.L	4.34 × TDA + 11.51
SVO.RC.L	2.27 × TDA + 6.85		SVO.SC.I	5.52 × TDA + 14.63
VOP.RC.I	2.89 × TDA + 8.7		HZO.SC.I	2.44 × TDA + 9.
SVO.RC.I	2.89 × TDA + 8.7		SOC.SC.I	1.76 × TDA + 0.36
HZO.RC.I	0.72 × TDA + 8.74		HCS.SC.I	0.38 × V + 0.88

*For this rulemaking, equipment class designations consist of a combination (in sequential order separated by periods) of (1) an equipment family code (VOP=vertical open, SVO=semivertical open, HZO=horizontal open, VCT=vertical transparent doors, VCS=vertical solid doors, HCT=horizontal transparent doors, HCS=horizontal solid doors, or SOC=service over counter); (2) an operating mode code (RC=remote condensing or SC=self-contained); and (3) a rating temperature code (M=medium temperature (38 °F)), L=low temperature (0 °F), or I=ice-cream temperature (-15 °F)). For example, "VOP.RC.M" refers to the "vertical open, remote condensing, medium temperature" equipment class.
** TDA is the total display area of the case, as measured in ARI Standard 1200-2006, appendix D.
† V is the volume of the case, as measured in ARI Standard 1200-2006, appendix C.

In addition to the standards in Table 1.4.1 and Table 1.4.2, the standard for equipment class SOC.SC.M, established by AEMTCA, is given by the expression 0.6 × TDA + 1.0, and has an effective date of January 1, 2012 (42 U.S.C. 6313(c)(4)).

1.4.4 Framework and Analysis Methodology

DOE initiated this rulemaking to fulfill its statutory requirements set forth in 42 U.S.C. 6313(c) with respect to establishing amended energy conservation standards for commercial refrigeration equipment. As the first step in April 2010, DOE published a *Rulemaking Framework for Commercial Refrigeration Equipment* (April 2010 framework document) describing the procedural and analytical approaches DOE anticipated using to evaluate the establishment of energy conservation standards for commercial refrigeration equipment. This document is available at www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/cre_framework_04-30-10.pdf

DOE held a public meeting on May 18, 2010 (May 2010 framework public meeting) to discuss procedural and analytical approaches to the rulemaking and to inform interested parties and facilitate their involvement in the rulemaking process. The analytical framework presented at the public meeting described different analyses, such as the engineering analysis and the LCC and PBP analyses, the methods proposed for conducting them, and the relationships among the various analyses.

After the analytical framework public meeting, as part of the information gathering and sharing process for the preliminary MIA, DOE organized and held interviews with CRE manufacturers. DOE selected companies that represented production of all types of commercial refrigeration equipment, ranging from small to large manufacturers. DOE had four objectives for these interviews: 1) solicit feedback on the draft engineering analysis (including methodology, production costs, manufacturing processes, and findings); 2) solicit feedback on topics related to the preliminary MIA; 3) provide an opportunity, early in the rulemaking process, for manufacturers to express specific concerns to DOE; and 4) foster cooperation between the manufacturers and DOE.

In March 2011, DOE published a notice of public meeting and availability of the preliminary TSD (March 2011 preliminary analysis) for the ongoing rulemaking to potentially amend energy conservation standards for commercial refrigeration equipment. This document is available at www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/fr_nopm_publication_2011_03_30.pdf

DOE held a public meeting on April 19, 2011 (April 2011 preliminary analysis public meeting) to give stakeholders the opportunity to comment on the proposed equipment classes DOE is considering; the analytical framework, models, and tools (*e.g.,* LCC and NES spreadsheets) that DOE has been using to perform analyses of the impacts of energy conservation standards; the results of the preliminary analyses; and the candidate energy conservation standard levels. See Table 1.4.3 for all the analyses discussed at the public meeting to be undertaken in each of the formal public rulemaking documents.

Table 1.4.3 CRE Analyses

Preliminary Analysis	NOPR	Final Rule*
Market and technology assessment	Revised preliminary analyses	Revised NOPR analyses
Screening analysis	Customer subgroup analysis	
Engineering analysis	Manufacturer impact analysis	
Energy use characterization	Utility impact analysis	
Markups to determine equipment price	Employment impact analysis	
LCC and PBP analyses	Emissions analysis	
Shipments analysis	Emissions monetization	
NIA	Regulatory impact analysis	
Preliminary MIA		

* During the final rule phase, DOE considers the comments submitted by the U.S. Department of Justice in the NOPR phase concerning the impact of any lessening of competition that is likely to result from the imposition of the standard. (42 U.S.C. 6295(o)(2)(B)(v))

After the posting of the March 2011 preliminary analysis TSD and the April 2011 preliminary analysis public meeting, DOE conducted interviews with CRE manufacturers as part of the MIA for the NOPR. A number of general topics were discussed during each interview: 1) general key issues; 2) company overview and organizational characteristics; 3) company financial parameters; 4) production cost breakdown; 5) shipment projections and market shares; 6) equipment mixes; 7) conversion costs; 8) markups and profitability; 9) cumulative regulatory burden; 10) exports, foreign competition, and outsourcing; 11) direct employment impact assessment; 12) market consolidation; and 13) baseline products and different design options.

DOE developed spreadsheets for the LCC and PBP analyses and for the NIA in an effort to meet the objectives of the Process Rule. The LCC spreadsheet calculates national distributions of LCC savings at all efficiency levels above the baseline. DOE also developed an NIA spreadsheet that calculates the NES and national NPVs at all efficiency levels. This spreadsheet includes a model that forecasts shipments for the various equipment classes of commercial refrigeration equipment at different efficiency levels.

DOE reviewed the recommendations made on April 21, 1998, by the Advisory Committee on Appliance Energy Efficiency Standards. (Advisory Committee, No. 96) These recommendations related to: 1) using the full range of consumer marginal energy rates (CMERs) in the LCC analysis (replacing the use of national average energy prices); 2) defining a range of energy price futures for each fuel used in the economic analyses; and 3) defining a range of primary energy conversion factors and associated emission reductions based on the generation of energy and emissions that would be displaced by energy efficiency standards for each rulemaking. DOE's analysis implemented 2) and 3) above; however, as discussed previously, DOE conducted the LCC analysis using regional average electricity prices for affected business types and did not develop CMERs in the LCC analysis.

1.5 STRUCTURE OF THE DOCUMENT

Listed below are the 17 TSD chapters and related appendices that collectively form the TSD.

Chapter 1	Introduction: provides an overview of the appliance standards program and how it applies to the CRE 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: provides DOE's definition of commercial refrigeration equipment, discusses the proposed equipment classes, and names the major industry players. This chapter also provides an overview of commercial refrigeration technology, including techniques employed to improve equipment efficiency.
Chapter 4	Screening Analysis: identifies all the design options that improve CRE efficiency, and determines which of these will be evaluated and which will be screened out.
Chapter 5	Engineering Analysis: presents detailed cost and efficiency information for the units of analysis. This chapter describes DOE's approach for determining manufacturer costs, including the markups used for converting material costs to manufacturer sales prices.
Chapter 6	Markups Analysis: presents the methodology used to determine the distribution channel markups that are used to convert manufacturer selling prices into customer purchase price of the equipment.
Chapter 7	Energy Use Analysis: DOE used the energy consumption model in the engineering analysis to estimate CRE energy use. DOE did not conduct a separate energy use analysis for this rulemaking.
Chapter 8	Life-Cycle Cost and Payback Period Analysis: presents the methodology used to estimate the impact of potential new or amended standards on customers of commercial refrigeration equipment by calculating LCC and PBP values at all higher efficiency levels.
Chapter 9	Shipments Analysis: presents the methodology used to estimate the historic and future shipments of commercial refrigeration equipment. The estimated shipments numbers are used as inputs to NIA and other downstream analyses.
Chapter 10	National Impact Analysis: presents the methodology used to estimate national impacts by calculating NES and NPV at all higher efficiency levels.

Chapter 11	Customer Subgroup Analysis: evaluates impacts on identifiable customer subgroups that may be disproportionately disadvantaged by the proposed new or amended standards.
Chapter 12	Manufacturer Impact Analysis: assesses the impacts on CRE manufacturers of any new or amended standards. In addition to financial impacts, a wide range of quantitative and qualitative effects may occur following adoption of a standard that may require changes to the manufacturing practices for this equipment.
Chapter 13	Emissions Analysis: presents the assessment of the impacts of proposed CRE standard levels on emissions of certain pollutants.
Chapter 14	Monetization of Emissions Reductions Benefits: presents the methodology to estimate monetary benefits likely to result from the reduced emissions of certain pollutants.
Chapter 15	Utility Impact Analysis: analyzes the effects of proposed new or amended CRE standard levels on the electric utility industry.
Chapter 16	Employment Impact Analysis: estimates national job creation or elimination (indirect effects) resulting from possible amended standards due to reallocation of the associated commercial expenditures for purchasing and operating equipment.
Chapter 17	Regulatory Impact Analysis: evaluates potential major alternatives to standards to achieve customer product energy efficiency.
Appendix 5A	Engineering Data: contains full engineering specifications for all equipment classes directly analyzed.
Appendix 6A	Data for Equipment Price Markups: presents detailed data used for markups analysis.
Appendix 8A	User Instructions For Life-Cycle Cost Spreadsheet: Presents user instructions for LCC spreadsheet.
Appendix 8B	Detailed Life-Cycle Cost and Payback Period Analysis Results: Presents detailed results from the LCC analysis.
Appendix 8C	Uncertainty and Variability in Life-Cycle Cost Analysis: Presents brief discussion on the uncertainty and variability analysis used in the LCC analysis.
Appendix 8D:	Estimation of Potential Equipment Price Trend for Commercial Refrigeration Equipment: Presents experiential learning analysis in the LCC analysis.
Appendix 10A	User Instructions for NIA Spreadsheet: Presents user instruction for the NIA spreadsheet.

Appendix 10B National Net Present Value Using Alternative Price Forecasts: Presents experiential learning sensitivity analysis results.

Appendix 10C Trial Standard Levels and Standards Equations: Presents the criteria for TSL selection and the proposed standards equation at each TSL.

Appendix 10D Full-Fuel-Cycle Multipliers: Presents the development of full-fuel-cycle coefficients

Appendix 10E RISC & OIRA Consolidated Information System (ROCIS) Tables: Presents the ROCIS[j] tables.

Appendix 12A Government Regulatory Impact Model (GRIM) Overview: Presents overview of the model used in the MIA.

Appendix 14A Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866: Presents the SCC analysis.

Appendix 14B Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866: technical model update: Presents updated SCC analysis.

[j] Regulatory Information Service Center (RISC) and Office of Information and Regulatory Affairs (OIRA) Combined Information System.

REFERENCES

1. U.S. Department of Energy–Energy Information Administration. *Annual Energy Outlook 2013*. 2013. Washington D.C. DOE/EIA-0383(2013).

CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

This chapter provides a description of the general analytical framework used by the U.S. Department of Energy (DOE) in developing standards and assessing the impacts for commercial refrigeration equipment. The description addresses the methodology, the analytical tools, and the relationship between the various analyses conducted in the rulemaking. The objective of the rulemaking process is to determine minimum efficiency standards for commercial refrigeration equipment that are technologically feasible and economically justified. In this context, economic justification includes consideration of the economic impact on manufacturers and consumers, the national benefits, the impacts on utilities, and the impacts from any lessening of competition.

Figure 2.1.1 summarizes the analytical components of the standards-setting process. The focus of this figure is the third column, identified as "Analysis." The columns labeled "Key Inputs" and "Key Outputs" indicate how the analyses fit into the rulemaking process, and how the analyses relate to each other. Key outputs are analytical results that feed directly into the standards-setting process. Dotted lines connecting analyses indicate types of information that feed from one analysis to another. Key inputs are the types of data and information that the analyses require. Some key inputs exist in public databases and DOE will also collect inputs from stakeholders or others with special knowledge. Inputs developed by the project team for the standards-setting process are presented and open for stakeholder review.

The analyses that DOE performed for the notice of proposed rulemaking (NOPR) include:

- a market and technology assessment to characterize the commercial refrigeration equipment market and review techniques and approaches used to produce more efficient commercial refrigeration equipment;
- a screening analysis to identify design options that improve commercial refrigeration equipment efficiency and to determine which should be evaluated and which should be screened out;
- an engineering analysis to estimate the relationship between the manufacturing cost of a commercial refrigeration unit and its performance;
- a markup analysis to convert manufacturer sales prices to customer purchase prices;
- an energy use analysis to estimate the energy consumption of the equipment (for this NOPR, DOE used the energy consumption model from the engineering analysis and did not conduct a separate energy use analysis);
- a life-cycle cost (LCC) and payback period (PBP) analysis to estimate the impact of potential new or amended standards on customers of commercial refrigeration equipment by calculating LCC and PBP values at all higher efficiency levels;
- a shipments analysis to estimate shipments of commercial refrigeration equipment over the time period examined in the analysis;

- a national impacts analysis to assess the aggregate impacts at the national level of net present value (NPV) of total customer savings and national energy savings (NES);
- a customer subgroup LCC analysis to evaluate impacts on identifiable groups of customers who may be disproportionately affected by new or amended standards;
- a manufacturer impact analysis (MIA) to estimate the financial impact of potential amended standards on commercial refrigeration equipment manufacturers and to calculate impacts on competition, employment at the manufacturing plant, and manufacturing capacity;
- an emissions analysis to provide estimates of the effects of amended energy conservation standards on emissions of carbon dioxide (CO_2), sulfur dioxide (SO_2), nitrogen oxides (NO_X), and mercury (Hg);
- a monetization of reduction of emission benefits from proposed standards;
- a utility impact analysis to estimate the effects of proposed standards on the installed capacity and generating base of electric utilities;
- an employment impact analysis to estimate the impacts of amended standards on net jobs eliminated or created in the general economy as a consequence of increased spending on the purchase price of commercial refrigeration equipment and reduced customer spending on energy; and
- a regulatory impact analysis (RIA) to explore major alternatives to proposed standards that could achieve comparable energy savings.

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

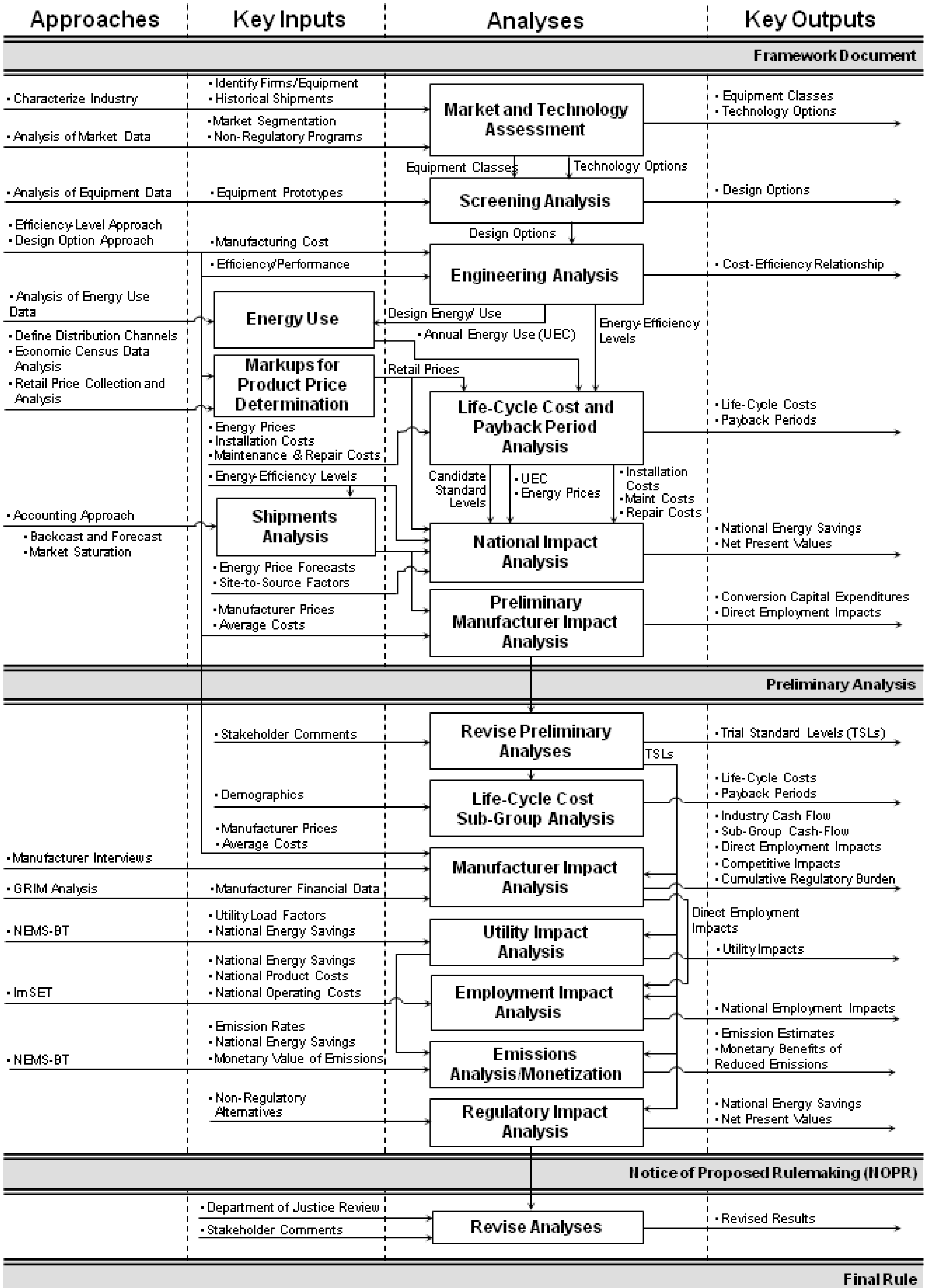

Figure 2.1.1 Analyses for Commercial Refrigeration Equipment Energy Conservation Standards

2.2 BACKGROUND

As described in chapter 1 of this technical support document (TSD), DOE announced a formal effort to consider further improvements to the process used to develop appliance efficiency standards. DOE called on energy efficiency groups, manufacturers, trade associations, state agencies utilities, and other interested parties to provide input to this effort. As a result of this combined effort, DOE published *Procedures, Interpretations and Policies for Consideration of New or Revised Energy Conservation Standards for Consumer Products* (the "Process Rule"), 10 CFR part 430, subpart C, appendix A. The Process Rule outlined the procedural improvements identified by the interested parties, and included a review of the (1) economic models; (2) analytical tools; (3) methodologies; (4) non-regulatory approaches; and (5) prioritization of future rules. The Process Rule recommended that DOE take into account uncertainty and variability by carrying out scenario or probability analysis. The following sections provide a general description of the analytical components of the improved rulemaking framework.

DOE developed the analytical framework pertaining to commercial refrigeration equipment in the *Rulemaking Framework for Commercial Refrigeration Equipment* (April 30, 2010). 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 May 6, 2010. 75 FR at 24824.

DOE presented the analytical approach to interested parties during a public meeting held on May 18, 2010.[1] DOE used comments gathered during the Framework public meeting as well as additional information for the preliminary analysis stage. DOE announced the notice of public meeting and the availability of the preliminary TSD[2] on March 30, 2011. 76 FR at 17573.

The following sections provide a brief overview of the different analytical approaches of this rulemaking analysis plan. DOE has used the most reliable data available at the time of each analysis in this rulemaking. DOE has also considered the submissions of additional data from interested parties during the rulemaking process.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the commercial refrigeration equipment market and existing technology options for making a unit of commercial refrigeration equipment more efficient.

2.3.1 Market Assessment

DOE reviewed relevant literature and interviewed manufacturers to develop an overall picture of the commercial refrigeration equipment industry in the United States. Industry publications and trade journals, government agencies, and trade organizations provided the bulk of the information, including (1) manufacturers and their market shares; (2) shipments by product type and capacity; (3) product information; and (4) industry trends.

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

When initiating a standards rulemaking, DOE develops information on the present and past industry structure and market characteristics of the product(s) concerned. This activity consists of both quantitative and qualitative efforts to assess the industry and products based on publicly available information.

2.3.2 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 commercial refrigeration equipment, as well as to highlight the developments within those technology categories and their applicability to these equipment classes. The result is a list of technology options to be analyzed in the screening analysis. Chapter 3 of the TSD includes a detailed list of all technology options DOE identified for this rulemaking.

2.4 SCREENING ANALYSIS

The purpose of the screening analysis is to evaluate the technologies identified in the technology assessment to determine which options to consider further in the analysis and which options to screen out. DOE consulted with industry, technical experts, and other interested parties in developing a list of energy-saving technologies for the technology assessment. DOE then applied the screening criteria to determine which technologies were unsuitable for further consideration in this rulemaking. Chapter 4 of the TSD, the screening analysis, contains details about DOE’s screening criteria.

The screening analysis examines whether various technologies (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on product utility or availability; and (4) have adverse impacts on health and safety. In consultation with interested parties, DOE reviewed the list of commercial refrigeration equipment technologies according to these criteria. In the engineering analysis, DOE further considers the efficiency-enhancement technologies that it did not eliminate in the screening analysis.

2.5 ENGINEERING ANALYSIS

The engineering analysis (chapter 5 of the TSD) develops cost-efficiency relationships for commercial refrigeration equipment, estimating manufacturer costs of achieving increased efficiency levels. Manufacturing costs are used as the means of determining retail prices in the LCC analysis, and are needed for the MIA. The engineering analysis also determines the maximum technologically feasible energy efficiency level.

In general, the engineering analysis estimates the efficiency improvement potential of the individual or combinations of design options that passed the four criteria in the screening analysis. DOE, in consultation with stakeholders, uses the most appropriate method to determine the manufacturing cost-energy efficiency relationship. This cost-efficiency relationship developed in the engineering analysis is used in the LCC analysis.

As described in TSD chapter 1, DOE will consider those commercial refrigeration equipment units that are designed to achieve the maximum improvement in energy efficiency that the Secretary of Energy determines are technologically feasible and economically justified. (42 U.S.C 6295(o)(2)(A)) Therefore, an important role of the engineering analysis is to identify the maximum technologically feasible level. The maximum technologically feasible level is one that is reached by the addition of efficiency improvements and/or design options, both commercially feasible and in prototypes, to the baseline units. DOE believes that the design options comprising the maximum technologically feasible level must have been physically demonstrated in at least a prototype form to be considered technologically feasible.

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 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 stated its intention to use a design-option approach for the engineering analysis, as it was the methodology employed in the 2009 final rule analyses and was found to be the approach most appropriate for the equipment and technologies on the market because this equipment is designed and marketed based on the inclusion of specific features and components, rather than being sold as possessing a certain, standardized efficiency rating. In a design-option approach, analysis is performed in terms of incremental increases in efficiency due to the implementation of selected design options. For each equipment class, the engineering analysis estimates manufacturer production costs for each successive design option. Stakeholder comments did not refute this choice of a design-option approach, and thus this approach was employed in the preliminary analysis and NOPR engineering analysis. DOE also augmented this approach with some reverse-engineering analysis to develop base manufacturing costs for portions of the equipment analyzed.

2.5.1 Baseline Models

In order to analyze design options for energy efficiency improvements, DOE defined a baseline model unit for each equipment class. DOE defined baseline models as units with the most popular and cost-effective features that are currently available on the market. It should be noted that this engineering baseline may, for some equipment classes, be comprised of less-efficient equipment than mandated by past standards, specifically the Energy Policy Act of 2005 and 2009 DOE final rule standards. This is due to the fact that the rulemaking analyses were conducted in advance of the compliance date of some of these standards. In its selection process, DOE considered technical descriptions of the covered equipment, definitions of the equipment classes as described in the previous rulemaking documents, results of the market assessment, and suggestions from stakeholders.

2.5.2 Manufacturing Cost Analysis

There are several ways to develop the relationship between cost and performance. DOE chose to use a design-option approach in this rulemaking. This approach identifies potential technological paths manufacturers could use to achieve increased equipment energy efficiency. To develop a base cost for the core case of the commercial refrigeration units, DOE purchased units available on the market for specific equipment classes and dismantled them component-by-component to develop a bill of materials and cost model for the core of the refrigerated case. DOE then parameterized and expanded this information to apply to all equipment classes being modeled. Then, in the engineering cost model, DOE added these core costs to the costs of the energy-consuming components, developed using independent costing methods in conjunction with manufacturer data. The result was a cost for an entire production unit at each of the efficiency levels analyzed.

2.6 MARKUPS FOR EQUIPMENT PRICE DETERMINATION

DOE used the markup analysis to determine distribution channel markups that were used to convert the manufacturer selling price (MSP) of the equipment into customer purchase price. DOE identified three different major channels through which the customers purchase commercial refrigeration equipment. DOE then determined the market shares of each distribution channel. The markup values associated with each distribution channel were calculated from the industry profit data. Sales tax is an additional markup in addition to the markups associated with distribution channels. DOE calculated a weighted-average sales tax for the entire nation. Finally, the overall markups were calculated by weighted-averaging the distribution channel markups and adding the weighted-average sales tax. DOE calculated baseline markups that were applied to baseline MSPs and incremental markups that were applied to MSP increments at higher efficiency levels. See TSD chapter 6 for details on the markups analysis.

2.7 ENERGY USE ANALYSIS

Based on the energy use analysis conducted as part of the 2009 final rule analysis, DOE concluded that the energy consumption model, which is part of the engineering analysis, was sufficiently accurate to calculate the energy use of commercial refrigeration equipment. Therefore, DOE did not conduct a separate energy use analysis as part of this rulemaking.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

DOE carried out the LCC and PBP analysis to evaluate the economic impacts of possible amended energy conservation standards developed for commercial refrigeration equipment on individual commercial customers. The effect of standards on customers includes a change in operating cost (usually decreased) and a change in purchase cost (usually increased). Two metrics were used to determine the effect of standards on customers:

- **Life-cycle cost**. LCC is the total customer cost over the life of the equipment–the sum of installed cost (purchase and installation costs) and operating costs (maintenance, repair, and energy costs). Future operating costs are discounted to the time of purchase and summed over the lifetime of equipment.

- **Payback period**. PBP is the estimated amount of time it would take customers to recover the assumed higher purchase price of more-efficient equipment through lower operating costs.

An efficiency improvement to commercial refrigeration equipment that is financially attractive to a customer will typically have a low incremental PBP and a low incremental change in LCC associated with it.

As part of the engineering analysis (TSD chapter 5), design-option levels were ordered on the basis of increasing efficiency (decreased energy consumption) and increasing MSP values. The order was determined based on the cost-effectiveness of each design option; that is, the ratio of incremental cost increase to incremental energy savings. For the LCC and PBP analysis, DOE chose a maximum of eight levels, henceforth referred to as *efficiency levels*, from the list of engineering design-option levels.

The first efficiency level or baseline efficiency level (Level 1) in each equipment class represents the least efficient and the least expensive equipment in that equipment class. The higher efficiency levels (Level 2 and up) have a progressive increase in efficiency and cost from Level 1. The highest efficiency level in each equipment class corresponds to the maximum technologically feasible (max-tech) level (see TSD chapter 5 for details). DOE treats each efficiency level as a *candidate standard level* (CSL), as each efficiency level represents a potential standard level. The words "efficiency level" and "CSL" can be used interchangeably.

The installed cost of equipment to a customer is the sum of the equipment purchase price and installation costs. The purchase price includes manufacturer production cost, to which a manufacturer markup and outbound freight costs are applied to obtain the MSP. This value is calculated as part of the engineering analysis (TSD chapter 5). DOE then applies additional markups to the equipment to account for the markups associated with the distribution channels for this type of equipment (TSD chapter 6). Installation costs vary by state depending on the prevailing labor rates.

Operating costs for commercial refrigeration equipment are a sum of maintenance costs, repair costs, and energy costs. These costs are incurred over the life of the equipment and therefore are discounted to the base year (2017, which is the compliance date of the amended standards that will be established as part of this rulemaking). The sum of the installed cost and the operating cost, discounted to reflect the present value, is termed the LCC.

Generally, customers incur higher installed costs when they purchase higher efficiency equipment, and these cost increments will be offset partially or wholly by savings in the operating costs over the lifetime of the equipment. Usually, the savings in operating costs are due to savings in energy costs because higher efficiency equipment uses less energy over the lifetime of the equipment. LCC savings are calculated for each CSL of each equipment class.

The PBP of a CSL is obtained by dividing the increase in the installed cost (from the baseline efficiency level) by the decrease in annual operating cost (from the baseline efficiency level). For this calculation, DOE uses the first year operating cost changes as the estimate of the decrease in operating cost, noting that some of the repair and replacement costs used herein are annualized estimates of costs. PBP is calculated for each CSL of each equipment class.

Apart from MSP, installation costs, and maintenance and repair costs, other important inputs for the LCC analysis are markups and sales tax, equipment energy consumption, electricity prices and future price trends, equipment lifetime, and discount rates.

Many inputs for the LCC analysis are estimated from the best available data in the market, and in some cases the inputs are generally accepted representative values within the commercial refrigeration equipment industry. However, in most cases each input has a range of values. For example, even though the average (and representative) lifetime of commercial refrigeration units in certain equipment classes may be 10 years, in general, equipment lifetimes of a typical refrigerator belonging to that equipment class may vary from 5 years to 15 years. While calculations based on the representative values yield average or representative values for the outputs (such as LCC or PBP), such values do not give an estimate of the ranges of values that these outputs could lie in. Therefore, DOE performed the LCC analysis in the form of Monte Carlo simulations in which certain inputs are provided a range of values and probability distributions. The results of the LCC analysis are presented in the form of mean and median LCC savings; percentages of customers experiencing net savings, net cost, and no impact in LCC; and median PBP. For each equipment class, 10,000 Monte Carlo simulations were carried out. The simulations were conducted using Microsoft Excel and Crystal Ball, a commercially available Excel add-in for carrying out Monte Carlo simulations.

Usually, the equipment available in the market will have a distribution of efficiencies, that is, each CSL within an equipment class will have a corresponding market share associated with it. Usually, within an equipment class, the market share of the baseline efficiency level is the highest and the market share values decrease with an increase in CSL. LCC savings and PBP are calculated by comparing the installed costs and LCC values of the standards-case scenarios against those of the base-case scenario. The base-case scenario is the scenario in which equipment is assumed to be purchased by customers in the absence of the proposed amended energy conservation standards. Standards-case scenarios are scenarios in which equipment is assumed to be purchased by customers after the amended energy conservation standards go into effect. The number of standards-case scenarios for an equipment class is equal to one less than the total number of efficiency levels in that equipment class because each CSL above the baseline efficiency level represents a potential new standard. For the standards-case scenario at a particular CSL, the market share of the efficiency levels were obtained using a roll-up scenario, in which market shares of the efficiency levels (in the base-case scenario) below the corresponding CSL were rolled-up into the CSL. For the base-case scenario in the LCC analysis, DOE calculated the market shares of the efficiency levels using a method described in TSD chapter 10.

Recognizing that each commercial building that uses the commercial refrigeration equipment is unique, DOE analyzed the LCC and PBP calculations for seven types of businesses: (1) supermarkets; (2) wholesaler/retailer multi-line stores, such as “big-box stores,” “warehouses,” and “supercenters”; (3) convenience and small specialty stores, such as meat markets, wine, beer, and liquor stores; (4) convenience stores associated with gasoline stations; (5) full-service restaurants; (6) limited service restaurants; and (7) other foodservice businesses, such as caterers and cafeterias. Different types of businesses face different energy prices and also exhibit differing discount rates that they apply to purchase decisions.

Equipment lifetime is another input that does not justify usage of a single value for each equipment class. Therefore, DOE assumes a distribution of equipment lifetimes that are defined by Weibull survival functions.

Another important factor influencing the LCC analysis is the state (location) in which the commercial refrigeration equipment is installed. Inputs that vary based on this factor include energy prices, installation costs, contractor markups, and sales tax. At the national level, the spreadsheets explicitly modeled variability in the model inputs for electricity price and markups using probability distributions based on the relative shipments of units to different states and business types.

2.9 SHIPMENTS ANALYSIS

Commercial refrigeration equipment shipment numbers are key inputs to the NES analysis, NPV calculations, and the MIA. Shipments analysis is used to estimate future commercial refrigeration equipment shipments over the national impact analysis period.

DOE calculated the historical shipments of commercial refrigeration equipment for the year 2009 based various shipments data sources. DOE then used the *Annual Energy Outlook*[3] 2013 (*AEO2013)* forecasts of commercial floor space additions, equipment lifetimes, and estimates of existing equipment stock to calculate the future shipments.

TSD chapter 9 presents the mathematical formulation of the shipment analysis model and the methodology used to estimate historical and future shipments of commercial refrigeration equipment.

2.10 NATIONAL IMPACT ANALYSIS

NES and NPV impacts are the cumulative energy and economic effects of an amended commercial refrigeration equipment energy conservation standard (TSD chapter 10). DOE projected the impacts from the year the standard would take effect through a selected number of years in the future. DOE analyzed energy savings, energy cost savings, equipment costs, and NPV of savings (or costs) for each CSL. The national energy and cost savings (or increases) that would result from amended energy conservation standards depend on the projected energy savings per unit and the anticipated amount of equipment sold. DOE created base-case shipment projections that include units at various efficiency levels. It based the projections on historical information plus forecasts of market influences, national economic growth, and electricity consumption. DOE then derived energy savings for various CSLs from the cost-efficiency schedules.

To make the analysis more accessible and transparent to all stakeholders, DOE used an Excel spreadsheet model to calculate the NES and the NPV (*i.e.,* national economic costs and savings from new standards). Users can change input quantities within the spreadsheet to test the impact of alternative input assumptions. Unlike the LCC analysis, the NES spreadsheet does not use distributions for inputs or outputs. Users can demonstrate sensitivities by running different scenarios using the spreadsheet.

As discussed in TSD chapter 10, the national impact analysis assesses the NPV of total consumer LCC and NES. DOE conducted an assessment of the aggregate impacts at the national level for the NOPR. Analyzing impacts of Federal energy conservation standards requires a comparison of projected U.S. energy consumption with and without amended standards. The base case, which is the projected U.S. energy consumption without standard, includes the mix of efficiencies being sold at the time the standard becomes effective.

DOE estimated national energy consumption for each year beginning with the expected effective date of the standard. DOE calculated national annual energy savings as the difference between two projections: a base case and a standards case.

DOE has historically presented NES in terms of primary energy savings. DOE has begun to also estimate full-fuel-cycle energy savings. 76 FR 51282 (August 18, 2011), as amended at 77 FR 49701 (August 17, 2012). The full-fuel-cycle (FFC) metric includes the energy consumed in extracting, processing, and transporting primary fuels, and thus presents a more complete picture of the impacts of energy efficiency standards. DOE's approach is based on the calculation of an FFC multiplier for each of the energy types used by covered equipment.

While DOE stated in that notice that it intended to use the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model to conduct the analysis, it also said it would review alternative methods, including the use 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 the *Annual Energy Outlook (AEO).* After evaluating both models and the approaches discussed in the August 18, 2011 notice, DOE has determined NEMS is a more appropriate tool for this application. 77 FR 49701 (Aug. 17, 2012). Therefore, DOE is using the NEMS model to conduct FFC analyses. For the NOPR analysis, DOE calculated FFC energy savings using a methodology described in appendix 10D. Chapter 10 of this TSD presents both the primary NES and the FFC energy savings for the considered trial standard levels (TSLs).

2.11 CUSTOMER SUBGROUP ANALYSIS

The customer subgroup analysis evaluates impacts on identifiable groups of customers of commercial refrigeration equipment who may be disproportionately disadvantaged by amended energy conservation standards. The LCC and PBP analysis described in chapter 8 of this TSD is applied to seven major types of businesses belonging to the food-retail and foodservice sectors that use a majority of the commercial refrigeration equipment. Although the inputs for different types of businesses are different in the LCC and PBP analysis, the final results may not reflect the results experienced by certain customer subgroups. In other words, some of the adverse impacts on businesses that are disproportionately disadvantaged may be masked by the averaging effect of the LCC and PBP analysis. Therefore, DOE carried out the customer subgroup analysis

[a] For more information on NEMS, refer to DOE EIA documentation. A useful summary is *National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003), March 2003.

by using the LCC and PBP analysis spreadsheet, but applying the inputs that are applicable only to the identified subgroups.

In general, the subgroups that face higher cost of capital and lower electricity price rates are more disadvantaged than others. Higher cost of capital imposes burden on the businesses because they have to borrow additional capital to purchase equipment that meets new or amended standards, compared to the case of where there are no new or amended standards. Lower electricity price rates result in lower savings in energy costs and, consequently, lower LCC savings and higher PBPs.

DOE carried out two customer subgroup analyses, one each for full-service restaurants and gasoline stations with convenience stores, by using the LCC spreadsheet described in TSD chapter 8, but with certain modifications. The input for business type was fixed to the identified subgroup, which ensured that the discount rates and electricity price rates associated with only that subgroup were selected in the Monte Carlo simulations (see TSD chapter 8). Additionally, a small business premium was added to the discount rate to reflect the higher discount rates faced by small businesses. Another major change from the LCC analysis was an added assumption that the subgroups do not have access to national accounts, which results in higher distribution channel markups for the subgroups, leading to higher equipment purchase prices. Apart from these changes, all other inputs for the customer subgroup analysis are same as those in the LCC analysis described in TSD chapter 8.

2.12 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 this 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.

2.13 EMISSIONS ANALYSIS

In the emissions analysis, DOE estimated the reduction in power sector emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur dioxide (SO_2) and mercury (Hg) from potential energy conservation standards for commercial refrigeration equipment. In addition, DOE estimated emissions impacts in production activities (extracting, processing, and transporting fuels) that provide the energy inputs to power plants. These are referred to as "upstream" emissions. Together, these emissions account for the FFC. In accordance with DOE's FFC Statement of Policy (76 FR 51282 (Aug. 18, 2011)), as amended at 77 FR 49701 (August 17, 2012), the FFC analysis includes impacts on emissions of methane (CH4) and nitrous oxide (N2O), both of which are recognized as greenhouse gases.

DOE conducted the emissions analysis using emissions factors derived from data in the latest version of EIA's *AEO2013*, supplemented by data from other sources. DOE developed separate emissions factors for power sector emissions and upstream emissions. The method that DOE used to derive emissions factors is described in chapter 13 of the NOPR TSD.

EIA prepares the AEO using the NEMS. Each annual version of NEMS incorporates the projected impacts of existing air quality regulations on emissions. *AEO2013* generally represents current legislation and environmental regulations, including recent government actions, for which implementing regulations were available as of December 31, 2012.

SO2 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 SO2 for affected EGUs in the 48 contiguous States and the District of Columbia (D.C.). SO2 emissions from 28 eastern States and D.C. were also limited under the Clean Air Interstate Rule (CAIR), which created an allowance-based trading program that operates along with the Title IV program in those States and D.C. 70 FR 25162 (May 12, 2005). CAIR was remanded to the U.S. Environmental Protection Agency (EPA) by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit), but 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; also known as the Transport Rule). 76 FR 48208 (August 8, 2011). On August 21, 2012, the D.C. Circuit issued a decision to vacate CSAPR. See EME Homer City Generation, LP v. EPA, 696 F.3d 7, 38 (D.C. Cir. 2012). The court ordered EPA to continue administering CAIR. The *AEO2013* emissions factors used for today's NOPR assume that CAIR remains a binding regulation through 2040.

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 SO2 emissions allowances resulting from the lower electricity demand caused by the adoption of an efficiency standard could be used to permit offsetting increases in SO2 emissions by any regulated EGU. In past rulemakings, DOE recognized that there was uncertainty about the effects of efficiency standards on SO2 emissions covered by the existing cap-and-trade system, but it concluded that no reductions in power sector emissions would occur for SO2 as a result of standards.

Beginning in 2015, however, SO2 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). In the final MATS rule, EPA established a standard for HCl as a surrogate for acid gas hazardous air pollutants (HAP), and also established a standard for SO2 (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, SO2 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. *AEO2013* 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 SO2 emissions. Under the MATS, NEMS shows a reduction in SO2 emissions when electricity demand decreases (e.g., as a result of energy efficiency standards). Emissions will be far below the cap established by CAIR, so it is unlikely that excess SO2 emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in SO2 emissions by any regulated EGU. Therefore, DOE believes that efficiency standards will reduce SO2 emissions in 2015 and beyond.

CAIR established a cap on NOx emissions in eastern States and the District of Columbia. Energy conservation standards are expected to have little or no physical effect on these emissions in those States covered by CAIR because excess NOx emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in NOx emissions. However, standards would be expected to reduce NOx emissions in the States not affected by caps, so DOE estimated NOx emissions reductions from the standards considered in today's NOPR for these 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 will estimate mercury emissions reduction using emissions factors based on *AEO2013*, which incorporates the MATS.

2.14 MONETIZATION OF EMISSIONS REDUCTIONS BENEFITS

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

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

The Interagency Working Group on SCC released an update of its previous report in 2013.[b] The most recent estimates of the SCC in 2015, expressed in 2012$, are $12.9, $40.8, $62.2, and $117 per metric ton of CO_2 avoided. For emissions reductions that occur in later years, these values grow in real terms over time. Additionally, the interagency group determined

[b] 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

that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although DOE gives preference to consideration of the global benefits of reducing CO_2 emissions.

DOE multiplies 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 discounts 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 estimates the potential monetary benefit of reduced NO_x emissions resulting from the standard levels it considers. For NO_x emissions, estimates suggest a very wide range of monetary values, ranging from 468 to $4,809 per ton in 2012$).[c] In accordance with OMB guidance, [d] DOE calculates a range of monetary benefits using each of the economic values for NO_x and real discount rates of 3 percent and 7 percent.

DOE is evaluating appropriate valuation of avoided SO_2 and Hg emissions. Whether monetization of reduced Hg emissions will occur in this rulemaking is yet to be determined.

2.15 UTILITY IMPACT ANALYSIS

DOE analyzed specific effects of its proposed standard levels on the electric utility industry as part of the NOPR analyses, using a variant of the DOE EIA NEMS. The version of NEMS used for appliance standards analysis is called NEMS-Building Technologies (NEMS-BT)[e] and is based on the *AEO2013* Reference Case with minor modifications.

The utility impact analysis reports the changes in installed capacity and generation, by fuel type, that result from the adoption of new efficiency standards at each TSL, as well as changes in electricity consumption.

2.16 EMPLOYMENT IMPACT ANALYSIS

The imposition of standards can affect employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the factories that produce the covered equipment, along with the affiliated distribution and service companies, resulting from the imposition of new standards. DOE evaluates direct employment impacts in the MIA. Indirect

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

[d] OMB, Circular A-4: Regulatory Analysis (Sept. 17, 2003).

[e] EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on EIA assumptions, DOE refers to it by the name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed). NEMS-BT was previously called NEMS-BRS.

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 imposition of standards. The combined direct and indirect employment effects are investigated in the employment impact analysis using the Pacific Northwest National Laboratory's "Impact of Sector Energy Technologies" (ImSET) model. The ImSET model was developed for DOE's Office of Planning, Budget, and Analysis, and estimates the employment and income effects of energy-saving technologies 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.

2.17 REGULATORY IMPACT ANALYSIS

In the NOPR stage, DOE prepared an RIA pursuant to Executive Order 12866, *Regulatory Planning and Review*, 58 FR 51735 (Oct. 4, 1993), which is subject to review under the Executive Order by the Office of Information and Regulatory Affairs at the Office of Management and Budget. The RIA addressed the potential for non-regulatory approaches to supplant or augment energy conservation standards to improve the energy efficiency or reduce the energy consumption of the commercial refrigeration equipment covered under this rulemaking.

2.18 DEPARTMENT OF JUSTICE REVIEW

Section 325(o)(2)(B)(i)(V) of the Energy Policy and Conservation Act states that before the Secretary of Energy may prescribe a new or amended energy conservation standard, the Secretary shall ask the Attorney General to make a determination of "the impact of any lessening of competition…that is likely to result from the imposition of the standard." (42 U.S.C. 6295) Pursuant to this requirement, DOE will solicit the views of the Department of Justice (DOJ) on any lessening of competition that is likely to result from the imposition of a proposed standard and will give the views provided full consideration in assessing the economic justification of a proposed standard. DOE may consult with DOJ at earlier stages in the standards development process to seek to obtain preliminary views on competitive impacts.

REFERENCES

1. U.S. Department of Energy-Office of Energy Efficiency and Renewable Energy Building Technologies Program. Rulemaking Framework for Commercial Refrigeration Equipment. 2010. Washington, D.C. < http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/52>

2. U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy. Preliminary Technical Support Document: Energy Conservation Program for Certain Commercial and Industrial Equipment: Commercial Refrigeration Equipment. April 2011. Washington, D.C. <http://www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0003-0030>

3. 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/>

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter details the market and technology assessment that the U.S. Department of Energy (DOE) has conducted in support of the ongoing energy conservation standards rulemaking for commercial refrigeration equipment, including self-contained and remote condensing commercial refrigerators, freezers, refrigerator-freezers, and ice-cream freezers; and self-contained commercial refrigerators with transparent doors designed for pull-down temperature applications.

The purpose of the market assessment is to develop a qualitative and quantitative characterization of the commercial refrigeration equipment industry and market structure based on publicly available information and information submitted by manufacturers and other stakeholders. Manufacturer characteristics and market shares, existing regulatory and non-regulatory efficiency improvement initiatives, equipment classes, and trends in markets and equipment characteristics are addressed. The purpose of the technology assessment is to develop a preliminary list of technologies that could improve the efficiency of commercial refrigeration equipment.

Commercial refrigeration equipment is primarily used in the food retail industry (*e.g.,* supermarkets, grocery stores, and convenience stores) and in the foodservice industry (*e.g.*, restaurants and cafeterias) to store, display, and merchandize perishable food products.

Definitions

Section 136(a)(3) of the Energy Policy Act of 2005 (EPACT 2005) amended section 340 of the Energy Policy and Conservation Act (EPCA), in part by adding subsection 340(9) (42 U.S.C 6311(9)) with definitions for the following terms that describe commercial refrigeration equipment:

> (9)(A) The term "commercial refrigerator, freezer, and refrigerator-freezer" means refrigeration equipment that—
>
> (i) is not a consumer product (as defined in section 321);
>
> (ii) is not designed and marketed exclusively for medical, scientific, or research purposes;
>
> (iii) operates at a chilled, frozen, combination chilled and frozen, or variable temperature;
>
> (iv) displays or stores merchandise and other perishable materials horizontally, semivertically, or vertically;
>
> (v) has transparent or solid doors, sliding or hinged doors, a combination of hinged, sliding, transparent, or solid doors, or no doors;

(vi) is designed for pull-down temperature applications or holding temperature applications; and

(vii) is connected to a self-contained condensing unit or to a remote condensing unit.

(B) The term "holding temperature application" means a use of commercial refrigeration equipment other than a pull-down temperature application, except a blast chiller or freezer.

* * *

(D) The term "pull-down temperature application" means a commercial refrigerator with doors that, when fully loaded with 12 ounce beverage cans at 90 degrees F, can cool those beverages to an average stable temperature of 38 degrees F in 12 hours or less.

(E) The term "remote condensing unit" means a factory-made assembly of refrigerating components designed to compress and liquefy a specific refrigerant that is remotely located from the refrigerated equipment and consists of one or more refrigerant compressors, refrigerant condensers, condenser fans and motors, and factory supplied accessories.

(F) The term "self-contained condensing unit" means a factory-made assembly of refrigerating components designed to compress and liquefy a specific refrigerant that is an integral part of the refrigerated equipment and consists of one or more refrigerant compressors, refrigerant condensers, condenser fans and motors, and factory supplied accessories.

(42 U.S.C. 6311(9))

EPACT 2005 does not explicitly define the terms "self-contained commercial refrigerator, freezer, or refrigerator-freezer" or "remote condensing commercial refrigerator, freezer, or refrigerator-freezer." DOE interpreted these two terms to mean "commercial refrigerator, freezer, or refrigerator-freezer that is connected to a self-contained condensing unit" and "commercial refrigerator, freezer, or refrigerator-freezer that is connected to a remote condensing unit," respectively.

Accordingly, the four categories of equipment covered under this rulemaking are as follows.

1. **Self-contained refrigerators, freezers, and refrigerator-freezers**: EPCA defines a "self-contained condensing unit," in part, as "an integral part of the refrigerated equipment." (42 U.S.C. 6311(9)(F)) Under the definitions quoted above, a self-contained commercial refrigerator, freezer, or refrigerator-freezer is a category of commercial refrigeration equipment in which the refrigerated cabinet and the condensing unit are integrated into one unit. Self-contained commercial refrigeration equipment is primarily used for storing, displaying, and/or merchandising food

products in small to medium-sized grocery and other food retail stores, restaurants and hotels, and in cafeteria-style foodservice venues. EPACT 2005 prescribed energy conservation standards for self-contained commercial refrigerators, freezers, and refrigerator-freezers with doors. For self-contained commercial refrigerators, freezers, and refrigerator-freezers without doors, DOE established energy conservation standards in DOE's 2009 commercial refrigeration equipment final rule. 74 FR 1092 (Jan. 9, 2009).

2. **Remote condensing commercial refrigerators, freezers, and refrigerator-freezers**: Under the definitions presented above, a remote condensing refrigerator, freezer, or refrigerator-freezer is a type of commercial refrigeration equipment that is connected to a remote condensing unit. Remote condensing commercial refrigeration equipment is generally used to display and merchandise food products in large retail installations like supermarkets and grocery stores. EPCA defines a "remote condensing unit," in part, as being "remotely-located from the refrigerated equipment." (42 U.S.C. 6311(9)(F)) DOE concluded during the 2009 rulemaking that the difference in language from the definition of "self-contained condensing unit" described above means that a remote condensing unit is not a part of the refrigerated equipment. 74 FR at 1104–1105 (Jan. 9, 2009). Therefore, in the 2009 final rule DOE adopted energy conservation standards for remote condensing commercial refrigerators, freezers, and refrigerator-freezers that apply to the refrigerated equipment, but not the remote condensing units.

3. **Self-contained commercial refrigerators designed for pull-down temperature applications**: EPCA defines "pull-down temperature application" to mean "a commercial refrigerator with doors that, when fully loaded with 12 ounce beverage cans at 90 degrees F, can cool those beverages to an average stable temperature of 38 degrees F in 12 hours or less." (42 U.S.C. 6311(9)(D)) Units fitting this description are typically known as beverage merchandisers or beverage coolers because of their use in displaying individually packaged beverages for sale. Even though this equipment has a similar configuration to self-contained refrigerators with transparent doors, EPCA prescribed separate standards for pull-down refrigerators with transparent doors. (42 U.S.C. 6313(c)(3)) Correspondingly, DOE intends to keep this equipment as a separate class in this rulemaking. Additionally, DOE notes that EPCA does not currently contain a standard for self-contained commercial refrigerators for pull-down temperature applications with solid doors or for equipment operating at other temperatures.

4. **Commercial ice-cream freezers**: On December 8, 2006, DOE published a final rule in which it adopted test procedures for commercial refrigeration equipment. In this final rule, DOE adopted the following definition for "ice-cream freezer": "a commercial freezer that is designed to operate at or below -5 °F (-21 °C) and that the manufacturer designs, markets, or intends for the storing, displaying, or dispensing of ice cream." 10 CFR 431.62, 71 FR at 71340, 71369. In addition, this final rule prescribed a rating temperature of -15°F for ice-cream freezers. 10 CFR 431.64, 71 FR at 71370 (Dec. 8, 2006). Under this definition, unless equipment is designed,

marketed, or intended specifically for the storage, display, or dispensing of ice cream, it would not be considered an "ice-cream freezer." Multi-purpose commercial freezers, manufactured for storage and display, for example, of frozen foods as well as ice cream would not meet this definition, and DOE would not treat them as commercial ice-cream freezers in this rulemaking. This is in accordance with the comments DOE received during the 2009 rulemaking that indicated that DOE should not classify such freezers as ice-cream freezers. 74 FR at 1103 (Jan. 9, 2009). On the other hand, any commercial freezer that is specifically manufactured for storing, displaying, or dispensing ice cream, and that is designed so that in normal operation it can operate at or below -5 °F (-21 °C), would meet the definition. This includes equipment that some interested parties referred to as true ice-cream cabinets—freezers that are designed to operate considerably below -5 °F (sometimes referred to as "hardening" cabinets) and are specifically designed for ice cream storage, for example—as well as those ice-cream dipping cabinets that are designed to operate below -5 °F.

3.2 MARKET ASSESSMENT

The following market assessment identifies the manufacturer trade association, domestic manufacturers of commercial refrigeration equipment, manufacturer market share, regulatory programs, and non-regulatory initiatives; defines equipment classes; provides historical shipment data, shipment projections, and equipment lifetime estimates; and summarizes market performance data.

3.2.1 Trade Association

The Air-Conditioning, Heating, and Refrigeration Institute (AHRI, formerly the Air-Conditioning and Refrigeration Institute, or ARI, before merging with the Gas Appliance Manufacturers Association, or GAMA, to form AHRI) is the most prominent trade association for commercial refrigeration equipment manufacturers. On January 12, 2005, ARI developed an agreement with member manufacturers to establish the Commercial Refrigerator Manufacturers Division (CRMD) within ARI and to develop and implement a certification program for commercial refrigerators, commercial freezers, and commercial refrigerator-freezers.

The CRMD was originally a separate trade organization founded in 1933. It serves supermarkets, food stores, convenience stores, restaurants, hotels, motels, food processing establishments, and hospitals. The 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;
- communicating with refrigerant suppliers and government agencies about environmentally acceptable refrigerants; and
- providing input to government agencies concerning regulations affecting the industry.

3.2.2 Manufacturers and Market Share

Current AHRI CRMD members are listed below; parent companies are shown in parentheses if applicable.[1]

- Continental Refrigerator
- CSC Worldwide (formerly Columbus Showcase)
- Hill Phoenix (Dover Corp.)
- Hoshizaki America, Inc.
- Hussmann (Ingersoll Rand)
- Killion Industries
- Kysor/Warren (Enodis)
- Master-Bilt Products (Standex)
- Southern Store Fixtures
- Structural Concepts Corp.
- Zero Zone

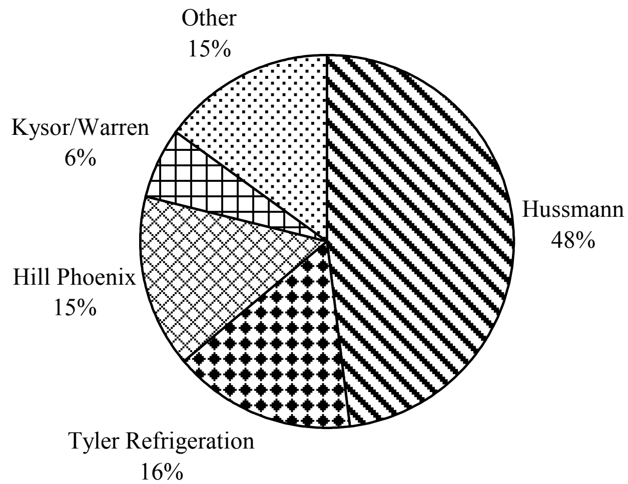
Other commercial refrigeration equipment manufacturers are listed below; parent companies are shown in parentheses if applicable.

- Amtekco
- Arctic Air
- Arctic Star
- Arneg USA
- Beverage-Air*
- Custom Deli
- Custom Fabricators
- Delfield (Manitowoc Food Service)*
- Howard/McCray
- Kelvinator (Electrolux)
- McCall Refrigeration (Manitowoc Food Service)*
- Northland Refrigeration
- Regal-Pinnacle
- Royal Store Fixtures (Parisi)
- Spartan Showcase
- Silver King
- Tor Rey Refrigeration
- Traulsen
- True Manufacturing
- Turbo Air
- Victory Refrigeration
- Vogel

*Current AHRI member

According to *Appliance Magazine*, which most recently published market share data for refrigerated display cases in 2005, four companies represented approximately 85 percent of the U.S. refrigerated display case market, with about 185,000 units shipped in 2004.[2] However, *Appliance Magazine* provides no precise definition of a refrigerated display case and it is therefore unclear what specific types of equipment the data covers—whether it is equipment that is self-contained or remote condensing, or equipment with doors or without doors.

As of 2004, Hussmann Corporation, a division of Ingersoll Rand, was the largest domestic manufacturer of refrigerated display cases according to the *Appliance Magazine* data, holding approximately 48 percent of the U.S. market (Figure 3.2.1).



Source: *Appliance Magazine*, "28th Annual Portrait of the U.S. Appliance Industry," September 2005.

Figure 3.2.1 Domestic Refrigerated Display Case Market Shares as of 2005

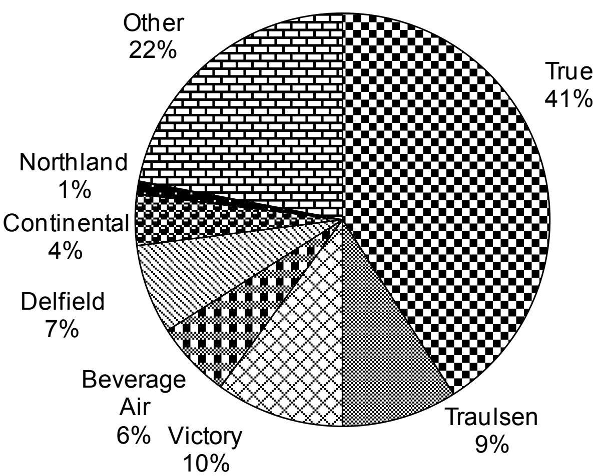
Manufacturers in the "Other" category (in Figure 3.2.1) are listed below; parent companies are listed in parenthesis if applicable.

- Arneg USA
- CSC Worldwide
- Federal Industries (Standex)
- Howard/McCray
- Killion Industries
- Master-Bilt Products (Standex)
- Regal-Pinnacle
- Royal Store Fixture (Parisi)
- Southern Store Fixtures
- Spartan Showcase
- Structural Concepts Corp.
- True Manufacturing
- Turbo Air
- Zero Zone

The landscape of the commercial refrigeration equipment market has changed since this data was collected in 2005. For example, Tyler Refrigeration no longer exists independently, and consolidation has occurred with large-market share companies having made acquisitions in the time since this data was collected. DOE has additional information regarding the commercial refrigeration equipment market share by company, but since that data was obtained from purchased reports that are not publicly available, DOE is not presenting that information in this technical support document (TSD).

Appliance Magazine also publishes data regarding market share for "commercial refrigerators." As is the case with refrigerated display cases, *Appliance Magazine* does not provide a precise definition of what a commercial refrigerator is. It is therefore unclear what specific types of equipment that data covers—whether it is equipment that is self-contained or remote condensing, or equipment with doors or without doors.

According to *Appliance Magazine*, which most recently published new data on the market share of commercial refrigerators in September 2009, seven companies comprised 78 percent of the U.S. commercial refrigerator market as of 2008. Of these, True Manufacturing represented the largest market share, with 41 percent. The additional six named companies comprised 37 percent of the market, and other manufacturers comprised the remaining 22 percent of the market (Figure 3.2.2).



Source: *Appliance Magazine*, "32nd Annual Portrait of the U.S. Appliance Industry," September 2009.

Figure 3.2.2 Domestic Commercial Refrigerator Market Share as of 2008

Manufacturers in the "Other" category (in Figure 3.2.2) are listed below; parent companies are listed in parentheses if applicable.

- Arctic Air
- Arctic Star
- CSC Worldwide
- Custom Deli
- Custom Fabricators
- Hill Phoenix (Dover Corp.)
- Hoshizaki America, Inc.
- Hussmann (Ingersoll Rand)
- Kelvinator
- Kysor/Warren (Enodis)
- Master-Bilt Products (Standex)
- McCall Refrigeration
- Silver King
- Structural Concepts Corp.
- Tor Rey Refrigeration
- Turbo Air
- Victory Refrigeration
- Zero Zone

3.2.2.1 Small Businesses

DOE is considering the possibility that energy conservation standards for commercial refrigeration equipment would adversely affect small businesses. The Small Business Administration (SBA) defines small business manufacturing enterprises for commercial refrigeration equipment as those having 750 employees or fewer.[3] 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 size that a for-profit company can have 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. For commercial refrigeration equipment, the size standard is matched to NAICS code 333415, *Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing*.

DOE studied the potential impacts on these small businesses in detail during the manufacturer impact analysis, which was conducted as a part of the notice of proposed rulemaking (NOPR) analysis. DOE identified a number of commercial refrigeration equipment manufacturers that qualify as small businesses, which are listed below; parent companies are listed in parentheses if applicable.

- Admiral Craft
- Amtekco
- Arctic Air
- Arctic Star
- Ascend Mfg.
- Beverage Air
- Blue Air Commercial Refrigeration
- ColdTech USA
- Continental Refrigerator
- CSC Worldwide
- Everest Refrigeration
- Fagor Refrigeration
- Fogel USA
- Global Refrigeration
- Howard/McCray
- Killion Industries
- MaxxCold
- Northland Refrigeration
- Regal-Pinnacle
- Royal Store Fixture (Parisi)
- Saturn Equipment
- Silver King
- Southern Store Fixtures
- Spartan Showcase
- Structural Concepts Corp.
- Summit Commercial
- Tor Rey Refrigeration
- Utility Refrigerator
- Victory Refrigeration
- Zero Zone

3.2.3 Regulatory Programs

Outside of the United States, Canada and Australia have efficiency standards for commercial refrigeration equipment. Additionally, the following states have established appliance efficiency regulations in the past: Arizona, California, Connecticut, Maryland, Massachusetts, Minnesota, New Jersey, New York, Oregon, Rhode Island, Vermont, and Washington. Of these, California is the only state that explicitly regulated all types of commercial refrigerators, freezers, and refrigerator-freezers with past state standards. Arizona, Oregon, Rhode Island, Connecticut, Maryland, New Jersey, New York, and Washington regulated certain types of commercial refrigeration equipment. Many of these standards have since been pre-empted by the Federal standards for self-contained equipment with doors set forth in EPACT 2005 and effective January 1, 2010. The documents that set forth individual state appliance efficiency standards can be accessed via the Database of State Incentives for Renewables & Efficiency (DSIRE), a DOE-funded online database.[4]

3.2.3.1 Natural Resources Canada

The Natural Resources Canada (NRCan) Office of Energy Efficiency has energy efficiency standards for commercial refrigerators, freezers, and refrigerator-freezers. A May 2010 NRCan bulletin proposed standards for self-contained equipment without doors, equipment with remote condensing units, and commercial ice cream freezers. These changes also serve to align the standards with those in the United States.[5] The test method for determining compliance is AHRI Standard 1200-2008, *Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets,* with the following specifications for the integrated average temperature (IAT):

- Refrigerator compartment: 38°F ± 2°F (3.3ºC ± 1.1ºC)
- Freezer compartment: 0°F ± 2°F (-17.8ºC ± 1.1ºC)
- Wine chiller: 45°F ± 2°F (7.2ºC ± 1.1ºC)
- Ice-cream cabinet: -5°F ± 2°F (-20.6ºC ± 1.1ºC)

3.2.3.2 Canadian Standards Association

The Canadian Standards Association (CSA) is an independent standards-setting agency that establishes test procedures and efficiency standards that the Canadian government typically adopts. The Canadian standard CAN/CSA C657-04, *Energy Performance Standard for Refrigerated Display Cabinets (Merchandisers)*, applies to remote condensing commercial equipment with and without doors, and self-contained commercial equipment with and without doors, except as covered by CSA C827-10. Commercial refrigerators and commercial freezers with doors (including commercial ice-cream freezers) are covered in a separate test procedure and standard, CSA C827-10, *Energy Performance Standard for Food Service Refrigerators and Freezers*. This standard is a revision of the original CSA standard published in 1995. Among the changes are redefined equipment categories and new minimum energy performance standards (MEPS).[a]

The CSA C657-04 standard divides commercial refrigeration equipment into seven classes and several sub-classes. Table 3.2.1 summarizes classes and MEPS levels from CSA C657-04. For equipment with a remote condensing unit, the MEPS use a pre-determined remote condensing unit efficiency to calculate daily energy use.

Table 3.2.1 Canadian Standards Association Equipment Classes and Efficiency Ratings

Class	IAT* *°F*	Temperature	Open/Closed	Deck	Number of Air Curtains	Angle of Air Curtain from Vertical	MEPS 2004 *kWh/ft per day*
1	41.0	Medium	Open	Single/Multi	1	0-30°	4.0
2	41.0	Medium	Open	Single/Multi	1	30-60°	2.9
3	41.0	Medium	Open	Single/Multi	1	60-90°	1.6
4	0.0	Low	Open	Multi	2 or 3	0-30°	9.4
5	0.0	Low	Open	Single	1	60-90°	4.6
6a	41.0	Low/Medium	Closed	Multi	Single Vent with Glass		2.3
6b	0.0	Same as 6a					6.1
7a	41.0	Medium	Closed	Single/Multi	Glass	N/A	2.6
7b	41.0	Same as 7a, except with only a gravity coil (no fan coil)					1.0

Source: CSA C657-04, *Energy Performance Standard for Refrigerated Display Cabinets (Merchandisers)*.
* IAT = the average temperature of all test packages recorded during testing.

[a] Changes to the standard make it extremely difficult to compare levels between the 1995 and updated standards.

3.2.3.3 Australia

Australia has required efficiency standards for commercial refrigeration equipment since October 1, 2004.[6] The standards apply to both remote condensing and self-contained commercial equipment used to store chilled and frozen food. The MEPS are established in Australian Standard (AS) 1731.14-2003 as total energy consumption per total display area (TEC/TDA) in kilowatt-hours per day per square meter for various equipment types. The Australian standards categorize equipment by the following criteria:

- remote or self-contained condensing unit
- lit shelves or unlit shelves
- number of shelves
- solid door or glass door
- fan coil or gravity coil
- high, medium, or low temperature

The standards also specify minimum energy performance by M-package temperatures (temperature of a load package) for self-contained cabinets. AS 1731-2003 specifies the test procedures used to measure energy consumption.

3.2.4 Non-Regulatory Initiatives

DOE reviewed several voluntary programs promoting energy efficient commercial refrigeration equipment in the United States, including the ENERGY STAR® program for commercial refrigerators and commercial freezers, the Consortium for Energy Efficiency (CEE) initiative for commercial refrigeration equipment, and the Federal Energy Management Program (FEMP) procurement program for energy efficient commercial refrigerators and commercial freezers. DOE also reviewed various rebate programs offered by utilities.

3.2.4.1 ENERGY STAR

The ENERGY STAR labeling program has a specification, in version 2.0 as of April 2009, for self-contained solid and glass door commercial refrigerators and commercial freezers.[7] This program does not apply to remote condensing commercial equipment or self-contained commercial equipment without doors. The ENERGY STAR version 2.0 specification criteria for commercial equipment list the maximum energy consumption as follows.

Table 3.2.2 ENERGY STAR Commercial Refrigerator and Freezer Key Criteria

Product Volume (in cubic feet)*	Refrigerator	Freezer
Vertical Configuration		
Solid Door Cabinets		
0 < V < 15	<= 0.089V + 1.411	<= 0.250V + 1.250
15 <= V < 30	<= 0.037V + 2.200	<= 0.400V - 1.000
30 <= V < 50	<= 0.056V + 1.635	<= 0.163V + 6.125
50 <= V	<= 0.060V + 1.416	<= 0.158V + 6.333
Glass Door Cabinets		
0 < V < 15	<= 0.118V + 1.382	<= 0.607V + 0.893
15 <= V < 30	<= 0.140V + 1.050	<= 0.733V - 1.000
30 <= V < 50	<= 0.088V + 2.625	<= 0.250V + 13.500
50 <= V	<= 0.110V + 1.500	<= 0.450V + 3.500
Chest Configuration		
Solid or Glass Door Cabinets	<= 0.125V + 0.475	<=0.270V + 0.130

*V = Association of Home Manufacturers (AHAM) volume in cubic feet

In addition to the scope of coverage, there are several notable differences between the ENERGY STAR criteria and those currently used by DOE. For one, ENERGY STAR uses the American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ANSI/ASHRAE) Standard 72-2005, *Method of Testing Commercial Refrigerators and Freezers*, as the sole method of test. As ASHRAE Standard 72-2005 incorporates the same rating temperatures as DOE for refrigerators and freezers and is the same test method referenced in AHRI Standard 1200 for self-contained refrigerators and freezers, this difference is nominal and does not impact the test result. The ENERGY STAR criteria also specify ANSI/AHAM HRF-1-2004 for measuring internal volume. The ENERGY STAR criteria also differ from DOE's existing standards in the treatment of energy management devices and in the definition of door type (solid or transparent) based on percentage of transparent area.

3.2.4.2 Consortium for Energy Efficiency

The CEE has a Commercial Kitchen Initiative, which encourages equipment purchasers to buy more efficient commercial refrigeration equipment and directs them toward other rebate programs for which these purchases may qualify them. The CEE program applies to solid door and glass-door reach-in commercial refrigerators and commercial freezers.[8] This program is based on ENERGY STAR version 2.0 standard levels, as listed in Table 3.2.2, and applies to self-contained commercial equipment with doors. The program specifies standard levels in terms of maximum daily energy use in kilowatt-hours per day for various door types for both vertical and horizontal equipment.

3.2.4.3 Federal Energy Management Program

FEMP is a program administered by DOE that oversees the Federal Government's energy management and investment initiatives. FEMP has established purchasing specifications for energy efficient equipment, including commercial refrigeration equipment, which Federal agencies must follow when buying new equipment for their facilities.[9] Federal purchasers are required by EPACT 2005 to purchase equipment that is either ENERGY STAR qualified or FEMP designated. The FEMP designated equipment consists of equipment that is in the upper 25 percent of energy efficiency in its class.

3.2.4.4 Rebate Programs

Numerous organizations and entities throughout the United States offer rebate programs for customers who purchase and install qualified commercial refrigeration equipment. Most of these incentive programs are accessible through the DSIRE online database. DSIRE lists all available incentives, including those offered by states, municipalities, utility companies, and the Federal government. This includes numerous incentives for purchasers of commercial refrigeration equipment units that meet specific criteria. While many entities offer rebates for commercial refrigeration equipment, most of which can be found on the DSIRE website, some are listed below as examples.

Efficiency Vermont, an organization offering technical assistance and financial incentives to encourage energy efficiency in Vermont, offers rebates for the installation of commercial refrigeration equipment that exhibits certain performance or design characteristics. These rebates include $100 for zero-energy transparent doors, $150 for light-emitting diode (LED) refrigerated display case light fixtures, and $6 per linear foot of display case strip curtains and continuous covers.[10]

The EnergySmart Grocer Program is funded by California utility ratepayers under the auspices of the California Public Utilities Commission. Eligible participants include grocery and convenience stores, food processors, and refrigerated warehouses operating in the Pacific Gas and Electric Company (PG&E) electric service territory. The program offers rebates for use of specific technologies on commercial equipment such as night covers on equipment without doors, upgrades to more efficient case lighting, anti-sweat heater controls, improved reach-in door gaskets, and electronically commutated permanent magnet (ECM) motors. Additionally, the program provides rebates to end users who replace older equipment with new high-efficiency equipment.[11]

NV Energy offers incentives promoting the installation of energy efficient commercial refrigeration equipment through the Nevada Sure Bet Program. These rebates are available to the utility's commercial, industrial, and institutional customers and are based on qualifying equipment from the ENERGY STAR program. Additionally, the program offers rebates for the installation of specific technologies, such as $4 per linear foot for the installation of night covers on commercial refrigeration equipment without doors and $30 per motor for the installation of ECM motors in refrigerated cases.[12]

Otter Tail Power Company offers rebates to Minnesota commercial customers under the Conservation Improvement Program. Under this program, customers are eligible to receive between $20 and $40 per linear foot of, or upgrade to, high-efficiency commercial refrigeration equipment, among other rebate offers.[13]

3.2.5 Equipment Classes

Commercial refrigeration equipment can be divided into various equipment classes categorized by physical characteristics that affect equipment efficiency. Most of these characteristics affect the kind of merchandise that the equipment can be used to display and determine how the customer can access that merchandise. Key physical characteristics are the operating temperature, the presence or absence of doors (closed cases or open cases), the type of doors used (transparent or solid), the angle of the door or air curtain (horizontal, semivertical, or vertical), and the type of condensing unit (remote condensing or self-contained). The following list shows the key characteristics of commercial refrigeration equipment that DOE developed as part of the 2009 final rule and identified in the Framework document and preliminary analysis for this rulemaking:

1. Operating temperature
   - Medium temperature (38 °F rating temperature, refrigerators)
   - Low temperature (0 °F rating temperature, freezers)
   - Ice-cream temperature (-15 °F rating temperature, ice-cream freezers)
2. Door type
   - Equipment with transparent doors
   - Equipment with solid doors
   - Equipment without doors
3. Orientation (air-curtain or door angle)
   - Horizontal
   - Semivertical
   - Vertical
4. Type of condensing unit
   - Remote condensing
   - Self-contained

Additionally, because this rulemaking covers equipment for which standards were set in the EPACT 2005 legislation, DOE has included a separate class for commercial refrigerators with transparent doors for pull-down temperature applications. The inclusion of this equipment as a separate class reflects the distinction that was made in the EPACT 2005 standards, which set specific standards for this type of equipment separate from the standards for other commercial refrigerators with transparent doors. DOE expressed its plans to include this equipment in the form of a separate family with a single class, and this was included in the May 2010 Framework document and March 2011 preliminary analysis. In response to stakeholder feedback, DOE has retained this designation in the NOPR.

Table 3.2.3 shows the nine commercial refrigeration equipment families DOE has considered within the scope of this rulemaking.

Table 3.2.3 Commercial Refrigeration Equipment Families

Equipment Family	Designation	Description
Vertical Open	VOP	Equipment without doors and an air-curtain angle ≥ 0° and < 10°
Semivertical Open	SVO	Equipment without doors and an air-curtain angle ≥ 10° and < 80°
Horizontal Open	HZO	Equipment without doors and an air-curtain angle ≥ 80°
Vertical Closed Transparent	VCT	Equipment with hinged or sliding transparent doors and a door angle < 45°
Vertical Closed Solid	VCS	Equipment with hinged or sliding solid (opaque) doors and a door angle ≥ 45°
Horizontal Closed Transparent	HCT	Equipment with hinged or sliding transparent doors and a door angle < 45°
Horizontal Closed Solid	HCS	Equipment with hinged or sliding solid (opaque) doors and a door angle ≥ 45°
Service Over Counter	SOC	Equipment with sliding or hinged doors intended for use by sales personnel and fixed or hinged glass for displaying merchandise
Pull-Down*	PD*	Commercial refrigerators with transparent doors for pull-down temperature applications

*This equipment family is only applicable to PD.SC.M

The first eight equipment families contain equipment that can have one of two condensing unit types and one of three operating temperatures. The ninth family, pull-down equipment, contains only a single class as defined by EPACT 2005. The condensing unit type has a significant impact on utility and energy use, and can be either remote condensing (RC) or self-contained (SC). Remote condensing equipment is typically more efficient on a normalized basis than self-contained equipment because of economies of scale incurred in the use of large, multiplex compressor rack systems that feed multiple units. Remote condensing equipment cannot be easily relocated, due to the refrigerant piping attachments, whereas self-contained equipment is more mobile, generally requiring only an electrical outlet for operation.

The operating temperature of the equipment also has a significant impact on utility and energy use. DOE has specified operating temperature classes of medium (M), low (L) or ice-cream (I), representing rating temperatures (or IAT) of 38 °F, 0 °F, or -15 °F, respectively (± 2 °F). Because different types of merchandise require different temperatures (*e.g.,* chilled versus frozen), operating temperature is a necessary distinction. Also, the larger temperature differences and thermodynamic behavior of refrigerants means that equipment with lower operating temperatures runs less efficiently than equipment with higher operating temperatures.

For open cases, "vertical" represents an air-curtain angle of < 10° from the vertical, "semivertical" represents an air-curtain angle of ≥ 10° and < 80° from the vertical, and "horizontal" represents an air-curtain angle of ≥ 80° from the vertical. DOE developed a definition for air-curtain angle as part of the January 2009 final rule analysis:

> (1) For equipment without doors and without a discharge air grille or discharge air honeycomb, the angle between a vertical line extended down from the highest point on the manufacturer's recommended load limit line and the load limit line

itself, when the equipment is viewed in cross- section; and (2) For all other equipment without doors, the angle formed between a vertical line and the straight line drawn by connecting the point at the inside edge of the discharge air opening with the point at the inside edge of the return air opening, when the equipment is viewed in cross-section.

Using all combinations of equipment family, operating mode, and temperature for the first eight families, plus the self-contained medium-temperature pull-down class, 49 equipment classes are possible, as illustrated in Table 3.2.4. DOE developed a lettering system in the 2009 rulemaking to simplify discussion of equipment classes, and has retained that system in this rulemaking. The lettering designation for a particular equipment class consists of the abbreviations for the equipment family, operating mode, and temperature, separated by periods. Table 3.2.4 shows a complete list of equipment classes with lettering designations organized by family, operating mode, and temperature.

Table 3.2.4 Commercial Refrigeration Equipment Classes

Equipment Family	Equipment Family Designation	Sample Equipment Family Image	Operating Mode Designation	Temperature Designation	Equipment Class Designation
Vertical Open	VOP		RC	M (38 °F)	VOP.RC.M
				L (0 °F)	VOP.RC.L
				I (-15 °F)	VOP.RC.I
			SC	M (38 °F)	VOP.SC.M
				L (0 °F)	VOP.SC.L
				I (-15 °F)	VOP.SC.I
Semivertical Open	SVO		RC	M (38 °F)	SVO.RC.M
				L (0 °F)	SVO.RC.L
				I (-15 °F)	SVO.RC.I
			SC	M (38 °F)	SVO.SC.M
				L (0 °F)	SVO.SC.L
				I (-15 °F)	SVO.SC.I
Horizontal Open	HZO		RC	M (38 °F)	HZO.RC.M
				L (0 °F)	HZO.RC.L
				I (-15 °F)	HZO.RC.I
			SC	M (38 °F)	HZO.SC.M
				L (0 °F)	HZO.SC.L
				I (-15 °F)	HZO.SC.I
Vertical Closed Transparent	VCT		RC	M (38 °F)	VCT.RC.M
				L (0 °F)	VCT.RC.L
				I (-15 °F)	VCT.RC.I
			SC	M (38 °F)	VCT.SC.M
				L (0 °F)	VCT.SC.L
				I (-15 °F)	VCT.SC.I
Vertical Closed Solid	VCS		RC	M (38 °F)	VCS.RC.M
				L (0 °F)	VCS.RC.L
				I (-15 °F)	VCS.RC.I
			SC	M (38 °F)	VCS.SC.M
				L (0 °F)	VCS.SC.L
				I (-15 °F)	VCS.SC.I
Horizontal Closed Transparent	HCT		RC	M (38 °F)	HCT.RC.M
				L (0 °F)	HCT.RC.L
				I (-15 °F)	HCT.RC.I
			SC	M (38 °F)	HCT.SC.M
				L (0 °F)	HCT.SC.L
				I (-15 °F)	HCT.SC.I
Horizontal Closed Solid	HCS		RC	M (38 °F)	HCS.RC.M
				L (0 °F)	HCS.RC.L
				I (-15 °F)	HCS.RC.I
			SC	M (38 °F)	HCS.SC.M
				L (0 °F)	HCS.SC.L
				I (-15 °F)	HCS.SC.I
Service Over Counter	SOC		RC	M (38 °F)	SOC.RC.M
				L (0 °F)	SOC.RC.L
				I (-15 °F)	SOC.RC.I
			SC	M (38 °F)	SOC.SC.M
				L (0 °F)	SOC.SC.L
				I (-15 °F)	SOC.SC.I
Pull-Down	PD		SC	M (38 °F)	PD.SC.M

3.2.6 Shipments

This section presents the shipments data DOE obtained to conduct the NOPR analyses. DOE gathered data from ARI (submitted as part of the 2009 DOE rulemaking process), Freedonia Group, the North American Association of Food Equipment Manufacturers (NAFEM), *Appliance Magazine*, and the U.S. Census Bureau.

3.2.6.1 ARI Data

As part of its comments on the Framework document for the 2009 rulemaking (Docket No. EE-2006-STD-0126, ARI, No. 7, Exhibit B at p. 1), ARI submitted annual shipment data by equipment class for its member companies for the year 2005. DOE used this shipments data as part of the basis for this analysis, as newer shipments data were not available. DOE understands that this data does not include the entire industry because ARI did not represent all manufacturers at that time.[b] However, because this data covered a significant portion of the commercial refrigeration equipment sold, and because no other detailed data was available at that time, the 2005 ARI shipments data was used as the total commercial refrigeration equipment shipments for the 2009 final rule, and has been incorporated as an input into the analyses for the current rulemaking.

Table 3.2.5 shows 2005 annual shipments for each category of commercial refrigeration equipment by equipment class. The ARI data included shipments for equipment that operates at an "application" temperature (*e.g.*, wine chillers that operate at 45 °F and freezers that operate at -30 °F). However, DOE only considered in its analyses shipments of equipment at the three temperatures used in this rulemaking (38 °F, 0 °F, and -15 °F; see section 3.2.5). The shipments of equipment that operate at one of these three temperatures constitute approximately 98 percent of the shipments that ARI reported.

[b] Most notably, True Manufacturing, which DOE understands to have a large market share of self-contained equipment.

Table 3.2.5 ARI 2005 Shipments of Commercial Refrigerators and Freezers by Equipment Class

Equipment Family	Equipment Family Designation	Operating Mode Designation	Temperature Designation	Equipment Class Designation	ARI Shipments*
Vertical Open	VOP	RC	M (38 °F)	VOP.RC.M	38,743
			L (0 °F)	VOP.RC.L	0
			I (-15 °F)	VOP.RC.I	0
		SC	M (38 °F)	VOP.SC.M	6,512
			L (0 °F)	VOP.SC.L	0
			I (-15 °F)	VOP.SC.I	0
Semivertical Open	SVO	RC	M (38 °F)	SVO.RC.M	29,552
			L (0 °F)	SVO.RC.L	0
			I (-15 °F)	SVO.RC.I	0
		SC	M (38 °F)	SVO.SC.M	9,750
			L (0 °F)	SVO.SC.L	0
			I (-15 °F)	SVO.SC.I	0
Horizontal Open	HZO	RC	M (38 °F)	HZO.RC.M	4,541
			L (0 °F)	HZO.RC.L	14,278
			I (-15 °F)	HZO.RC.I	0
		SC	M (38 °F)	HZO.SC.M	838
			L (0 °F)	HZO.SC.L	1,738
			I (-15 °F)	HZO.SC.I	0
Vertical Closed Transparent	VCT	RC	M (38 °F)	VCT.RC.M	2,767
			L (0 °F)	VCT.RC.L	38,483
			I (-15 °F)	VCT.RC.I	0
		SC	M (38 °F)	VCT.SC.M	43,374
			L (0 °F)	VCT.SC.L	2,472
			I (-15 °F)	VCT.SC.I	1,898
Vertical Closed Solid	VCS	RC	M (38 °F)	VCS.RC.M	49
			L (0 °F)	VCS.RC.L	2
			I (-15 °F)	VCS.RC.I	43
		SC	M (38 °F)	VCS.SC.M	4
			L (0 °F)	VCS.SC.L	4,202
			I (-15 °F)	VCS.SC.I	470
Horizontal Closed Transparent	HCT	RC	M (38 °F)	HCT.RC.M	0
			L (0 °F)	HCT.RC.L	15
			I (-15 °F)	HCT.RC.I	0
		SC	M (38 °F)	HCT.SC.M	724
			L (0 °F)	HCT.SC.L	0
			I (-15 °F)	HCT.SC.I	9,056
Horizontal Closed Solid	HCS	RC	M (38 °F)	HCS.RC.M	37
			L (0 °F)	HCS.RC.L	0
			I (-15 °F)	HCS.RC.I	0
		SC	M (38 °F)	HCS.SC.M	39,761
			L (0 °F)	HCS.SC.L	4,109
			I (-15 °F)	HCS.SC.I	0
Service Over Counter	SOC	RC	M (38 °F)	SOC.RC.M	9,312
			L (0 °F)	SOC.RC.L	9
			I (-15 °F)	SOC.RC.I	0
		SC	M (38 °F)	SOC.SC.M	1,108
			L (0 °F)	SOC.SC.L	0
			I (-15 °F)	SOC.SC.I	0
Pull-Down	PD	SC	M (38 °F)	PD.SC.M	N.A.**

* Source: Docket No. EE-2006-STD-0126, ARI, No. 7, Exhibit B at p. 1.

** Self-contained pull-down refrigerators with transparent doors were not explicitly addressed in the 2005 shipments data from ARI.

3.2.6.2 NAFEM Data

NAFEM publishes a biennial study of the foodservice equipment and supplies market. The latest available report is titled *2008 Size and Shape of the Industry Study*.[14] It contains survey data from NAFEM members (not all members provided data for the report) including shipments numbers and the value of sales in dollars. Based on the numbers reported by the respondents to the survey, NAFEM developed a total market estimate of shipments (units shipped and dollar sales) for the year 2007. NAFEM also estimated the projected shipments for 2008. NAFEM published similar study reports for shipments in 2006,[15] 2004,[16] and 2002.[17]

The "refrigeration and ice machine study" is part of the NAFEM reports and includes shipments data for under-counter, reach-in, pass-through, roll-in/roll-through refrigerators and freezers; air curtain refrigerators; milk coolers; and ice-cream cabinets, freezers, and dispensers (gelato equipment, dipping freezer/cabinets). Table 3.2.6 shows the DOE equipment classes to which the NAFEM equipment was assigned. Shipments numbers have been withheld from publication because the NAFEM reports are not publicly available documents.

Table 3.2.6 NAFEM Shipments Categories and Corresponding DOE Equipment Classes

NAFEM Category	Assigned DOE Equipment Class
Air curtains or air curtain refrigerators	VOP.SC.M
Milk coolers	VCS.SC.M
Under-counter refrigerators	VCS.SC.M
Under-counter freezers	VCS.SC.L
Reach-in/pass-through refrigerators	VCS.SC.M,VCT.SC.M
Reach-in/pass-through freezers	VCS.SC.L,VCT.SC.L
Roll-in/roll-through refrigerators	VCS.SC.M
Roll-in/roll-through freezers	VCS.SC.L
Ice-cream cabinets, freezers & dispensers (gelato equipment, dipping freezers/cabinets)	HCT.SC.I,HCT.SC.L, HCS.SC.I

3.2.6.3 Freedonia Market Reports

The Freedonia Group published a study on the United States commercial refrigeration industry titled *Commercial Refrigeration Equipment to 2014*.[18] This report contains dollar values of commercial refrigeration equipment sales and in some cases shipments data in number of units. Shipments data are reported by market type (food and beverage retail, foodservice), equipment type (open and closed display case, reach-ins), and operating temperature (normal, low, and ice-cream temperatures). The report also presents the year-on-year percentage changes in total commercial refrigeration market from 1999 to 2009, which includes commercial refrigeration equipment used in food production and food distribution market sectors, and other equipment categories like beverage vending machines, walk-ins, liquid chillers, transportation systems, and refrigeration parts. Table 3.2.7 shows the classification of the Freedonia equipment categories into DOE product classes. Shipments numbers have been withheld from publication because Freedonia reports are not publicly available.

Table 3.2.7 Freedonia Shipments Categories and Corresponding DOE Equipment Classes

Freedonia Equipment Type Designation	Freedonia Operating Temperature Designation	DOE Equipment Class(es)
Open self-service display cases	Normal	VOP.RC.M,HZO.RC.M,SVO.RC.M VOP.SC.M,SVO.SC.M,HZO.SC.M
Closed display cases	Normal	VCT.RC.M,VCT.SC.M
Open display cases	Low	VOP.RC.L,HZO.RC.L,SVO.RC.L VOP.SC.L,HZO.SC.L,SVO.SC.L
Closed display cases	Low	VCT.RC.L,VCT.SC.L, SOC.RC.L,SOC.SC.L
Ice-cream freezer & other	Ice-cream	VCT.RC.I,VCT.SC.I,HCT.SC.I, HCT.SC.L
Reach-in refrigerators	Normal	VCS.SC.M
Reach-ins freezers	Low	VCS.SC.L

3.2.6.4 *Appliance Magazine* Data

Appliance Magazine publishes historical and forecasted shipments of refrigerated display cases, shown in Table 3.2.8 and Table 3.2.9.[c]

Table 3.2.8 Historical Shipments of Refrigerated Display Cases

Year	Unit Shipments
1999	340,453
2000	347,262
2001	175,000
2002	183,300
2003	191,549
2004	185,000
2005	177,000
2006	180,540
2007	184,000
2008	172,129

Source: *Appliance Magazine*, "56th Annual Statistical Review," May 2009.

Table 3.2.9 Statistical Forecasts of Refrigerated Display Case Shipments

Year	Unit Shipments
2009	152,000
2010	156,000
2011	162,000
2012	166,000

Source: *Appliance Magazine*, "58th Annual Appliance Industry Forecasts," February 2010.

It is unclear what is responsible for the sharp decline in display case shipments between 2000 and 2001 reported by A*ppliance Magazine*. A similar decline is reported in other market literature.[19] DOE believes that some of the observed decline in shipments is the result of a general slowdown in the U.S. economy in the second and third quarters of 2001. Financial

[c] As mentioned earlier, *Appliance Magazine* describes the data as representing refrigerated display cases but does not provide a precise definition of the equipment. It is unclear what types of equipment this term covers—whether it is equipment that is self-contained or remote condensing, or equipment with doors or without doors.

reports by commercial refrigeration equipment manufacturers discuss depressed investment and uncertainty in the retail food industry between 2000 and 2005 as contributing to low sales of commercial refrigeration equipment. There may be other explanations, including possible changes in what equipment *Appliance Magazine* included in its categorization of "refrigerated display cases."

Appliance Magazine also published historical and forecasted shipments of commercial refrigerators, shown in Table 3.2.10 and Table 3.2.11.[d]

Table 3.2.10 Historical Shipments of Commercial Refrigerators

Year	Unit Shipments
1999	233,750
2000	245,437
2001	260,000
2002	263,000
2003	268,000
2004	275,000
2005	289,000
2006	307,000
2007	309,375

Source: *Appliance Magazine*, "54th Annual Statistical Review," May 2007, "31st Annual Portrait of the U.S. Appliance Industry," September 2008.

Table 3.2.11 Statistical Forecasts of Commercial Refrigerator Shipments

Year	Unit Shipments
2009	270,455
2010	275,323
2011	280,830

Source: *Appliance Magazine*, "57th Annual Appliance Industry Forecasts," January 2009.

Appliance Magazine appears to have stopped offering historical and forecast information on shipments of commercial refrigerators and display cases after 2010. Thus the information presented here reflects the latest available data from that source.

3.2.6.5 Census Bureau Data

The U.S. Census Bureau's Economic Census of Manufacturing Industry Series publishes statistics on the quantity and value of shipments for those companies with shipments over $100,000 in value.[20, 21, 22] There are eight categories for display cabinets and display cases, including reach-ins. These are sub-divided into reach-in, closed display, and open display.

Table 3.2.12 shows shipment data for open refrigerated display cases, which include both self-contained units without doors and remote condensing units without doors. It is not possible

[d] Similar to its treatment of refrigerated display cases, *Appliance Magazine* describes the data as representing commercial refrigerators, but does not provide a precise definition of the equipment. It is unclear what types of equipment this term covers—whether it is equipment that is self-contained or remote condensing, or equipment with doors or without doors.

to determine from Table 3.2.12 which shipments are for self-contained units and which are for remote condensing units since the census data reports these together.

Table 3.2.12 Shipments of Open Refrigerated Display Cases (Remote Condensing and Self-Contained)

Type	Open or Closed	Temperature	Survey Year	Number of Companies with Sales Over $100,000	Shipment Quantity *1,000s*	Shipment Value *$1,000*
Display Case One Level	Open	Normal	2007	15	(q)47.7	237,791
			2002	6	-	89,622
			1997	13	-	140,259
Display Case Multi Level	Open	Normal	2007	10	S	170,628
			2002	9	-	341,472
			1997	11	58.6	258,310
Display Case	Open	Frozen Food	2007	7	S	29,366
			2002	6	-	11,538
			1997	7	20.4	90,213

Source: U.S. Census, Economic Census, Manufacturing Industry Series 2007, http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=ECN&_tabId=ECN1&_submenuId=datasets_4&_lang=en;
U.S. Census, Economic Census, Manufacturing Industry Series 1997, EC97M-3334D, www.census.gov/epcd/www/97EC31.HTM;
U.S. Census, Economic Census, Manufacturing Industry Series 2002, EC02-31I-333415 (RV), www.census.gov/econ/census02.
* S - Withheld because estimate did not meet publication standards
**(q) - 20–29 percent estimated

Table 3.2.13 shows shipment data for closed refrigerated display cases, which include both self-contained units with doors and remote condensing units with doors. It is not possible to determine from Table 3.2.13 which shipments are for remote condensing units and which are for self-contained condensing units.

Table 3.2.13 Shipments of Closed Refrigerated Display Cases (Remote Condensing and Self-Contained)

Type	Open or Closed	Temperature	Survey Year	Number of Companies with Sales Over $100,000	Shipment Quantity *1,000s*	Shipment Value *$1,000*
Display Case	Closed	Normal	2007	8	S	108,627
			2002	11	-	50,601
			1997	15	-	91,892
Cabinet	Closed	Frozen Food	2007	7	S	25,100
			2002	8	-	20,618
			1997	9	-	112,873
Other Display Cases	Not stated	Low Temp.	2007	6	S	D
			2002	7	-	58,549
			1997	6	-	43,150

Source: U.S. Census, Economic Census, Manufacturing Industry Series 2007, http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=ECN&_tabId=ECN1&_submenuId=datasets_4&_lang=en;
U.S. Census, Economic Census, Manufacturing Industry Series 1997, EC97M-3334D, http://www.census.gov/epcd/www/97EC31.HTM;
U.S. Census, Economic Census, Manufacturing Industry Series 2002, EC02-31I-333415 (RV), http://www.census.gov/econ/census02.
* S - Withheld because estimate did not meet publication standards
** D - Withheld to avoid disclosing data for individual companies; data are included in higher level totals

Table 3.2.14 shows shipment data for commercial reach-in (vertical) cabinets. These cabinets can have either solid or glazed doors. It is not possible to determine from Table 3.2.14 which shipments are for remote condensing units and which shipments are for self-contained units.

Table 3.2.14 Shipments of Commercial Reach-In Cabinets (Remote Condensing and Self-Contained)

Type	Open or Closed	Temperature	Survey Year	Number of Companies with Sales Over $100,000	Shipment Quantity *1,000s*	Shipment Value *$1,000*
Display Cabinets - Not for Frozen Foods	Not Specified	Normal	2007	21	S	655,800
			2002	21	381.7	465,553
			1997	29	-	439,081
Display Cabinet	Not Specified	Low Temperature	2007	11	S	341,136
			2002	16	-	259,105
			1997	24	-	307,605

Source: U.S. Census, Economic Census, Manufacturing Industry Series 2007, http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=ECN&_tabId=ECN1&_submenuId=datasets_4&_lang=en;
U.S. Census, Economic Census, Manufacturing Industry Series 1997, EC97M-3334D, http://www.census.gov/epcd/www/97EC31.HTM;
U.S. Census, Economic Census, Manufacturing Industry Series 2002, EC02-31I-333415 (RV), http://www.census.gov/econ/census02.
*S - Withheld because estimate did not meet publication standards

In summary, although the U.S. Census Bureau data contain some limited shipments data that would be useful for conducting technical analyses, not enough detail is available to provide specific assessments for shipments within each of the primary categories covered in this rulemaking.

3.2.7 Equipment Lifetimes

DOE reviewed available literature and consulted with experts on commercial refrigeration equipment to establish typical equipment lifetimes. The literature and individuals consulted estimated a wide range of typical equipment lifetimes, shown in Table 3.2.15.

Individuals with experience in the manufacturing or distribution of commercial refrigeration equipment suggested a typical case life of 5 to 15 years. Experts in the field suggested that while the equipment is typically robust in design, much of the equipment is replaced for cosmetic reasons during store remodeling (typically every 10 years or so). One distributor suggested that U.S. tax depreciation schedules, which allow depreciation over a 5-year period for retail fixtures, including commercial refrigerators and commercial freezers,[23] are one driver for regular replacement of commercial refrigeration equipment in the United States.

Some literature suggested lifetimes of up to 20 years or more for commercial refrigeration equipment. Many of the studies cited here 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.[24] However, available literature and consultation with experts in the field suggested that smaller, independently owned grocery stores were more likely to keep equipment longer than larger chain stores.

Several industry experts and stakeholders suggested during interviews and in public meetings that there is a significant used and refurbished equipment market. However, DOE did not determine the size of the used market relative to the new market. 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. The difficulty in collecting used equipment of the same "look" for planned display case line-ups in retail stores 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 square feet) and 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. See TSD chapter 8 and chapter 9 for the equipment lifetime values used in the LCC and shipments analyses.

Table 3.2.15 Estimates for Commercial Refrigeration Equipment Lifetimes

Life	Reference
15 years	Heshong Mahone Group 2004[25]
5-7 years (large chains)	Verisae 2006[26]
15 years (smaller chains and independent grocers may go up to 20 years)	Verisae 2006[27]
7-15 years	Mark Ellis & Associates 2003[28]
15 years	Foster-Miller 2001[29]
15-20 years	U.S. Environmental Protection Agency 2001[30]
15 years	Arthur D. Little 2002[31]
9-10 years (9 years with doors, 10 years without doors)	CEC 2004[32]
5-15 years (typically 10 years)	Hansen 2006[33]
10 years	PG&E 2004[3]
7-10 years (remote condensing) 8-12 years (self-contained)	Intergovernmental Panel on Climate Change 2001[34]
7 years	Fisher 1991[35]
10-15 years	Navigant Consulting, Inc. 2009[36]

3.2.8 Market Performance Data

3.2.8.1 Remote Condensing Equipment

During the 2009 rulemaking, DOE conducted a survey of existing remote condensing refrigerated equipment from major manufacturers and compiled a performance database based on available information. Information such as total refrigeration load, evaporator temperature, lighting power draw, defrost power draw, and motor power draw were used to analytically determine calculated daily energy consumption (CDEC) according to the methodology of AHRI Standard 1200, *Performance Rating of Commercial Refrigerated Display Merchandisers and Storage Cabinets.*

This data was used to develop figures included in the market and technology assessment chapter of the 2009 final rule TSD showing the relationship between CDEC and TDA for the VOP.RC.M, SVO.RC.M, and HZO.RC.M classes, as well as a plot showing the relationship between air curtain angle and performance. Because the market baseline did not change between the 2009 final rule and the publication of the preliminary analysis TSD for the current rulemaking, DOE retained those figures in the preliminary analysis TSD chapter 3.

Since the publication of the preliminary analysis for the current rulemaking, the compliance date of the 2009 standards (January 1, 2012) has passed, altering the market baseline. DOE does not have sufficiently detailed information for specific equipment models to allow it to show similar plots representative of the current market. Based on discussions with manufacturers, DOE believes that many remote condensing equipment lines offer models at or near the baseline, with options to add higher-efficiency features upon customer request.

3.2.8.2 Self-Contained Equipment

For self-contained equipment, market performance plots were developed for selected equipment classes based on rated test data for this equipment from publicly accessible sources. These included the California Energy Commission (CEC), and ENERGY STAR directories. The rated energy consumption values, capacities, and equipment types were used to produce market performance plots for self-contained equipment classes. However, because these directories are produced by different parties independent from DOE and are in some cases voluntary, the data contained within them does not always align exactly with the DOE equipment classes, nor does it necessarily reflect the entire range of efficiencies on the market within a given equipment class. For example, for some classes currently covered under a TDA-based standard, only volume information was available in these directories. Figure 3.2.3 through Figure 3.2.10 show energy use as a function of size for select self-contained equipment classes.

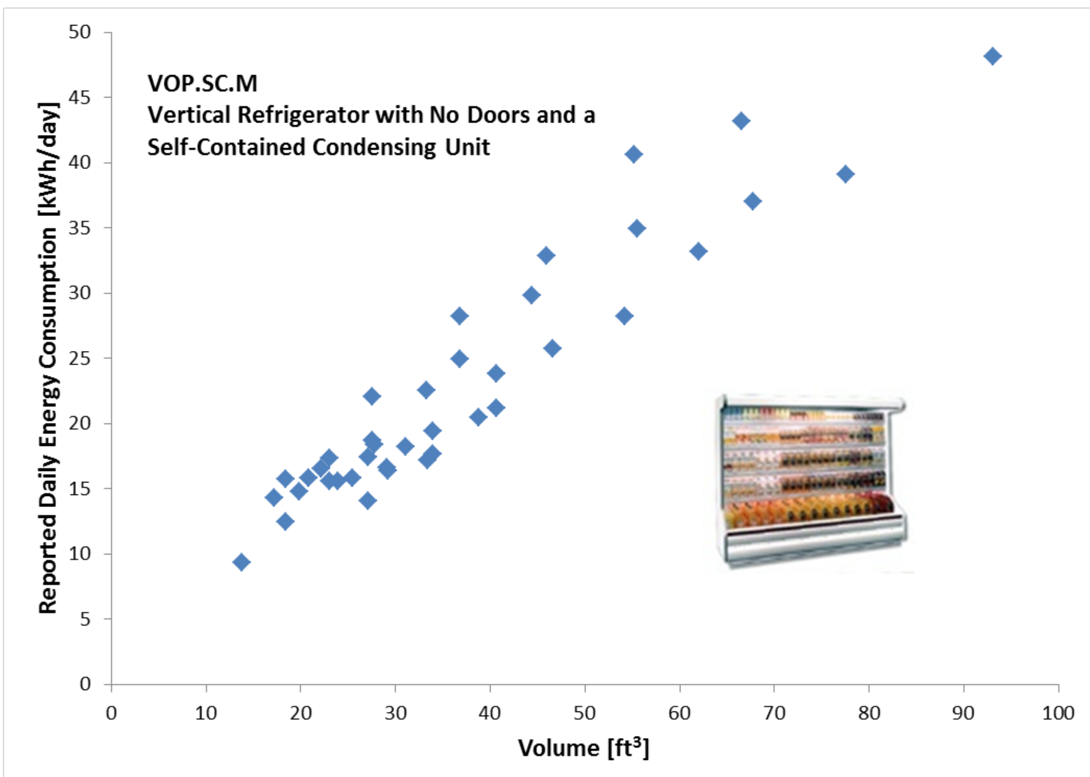


Figure 3.2.3 Market Performance Data for the VOP.SC.M Equipment Class

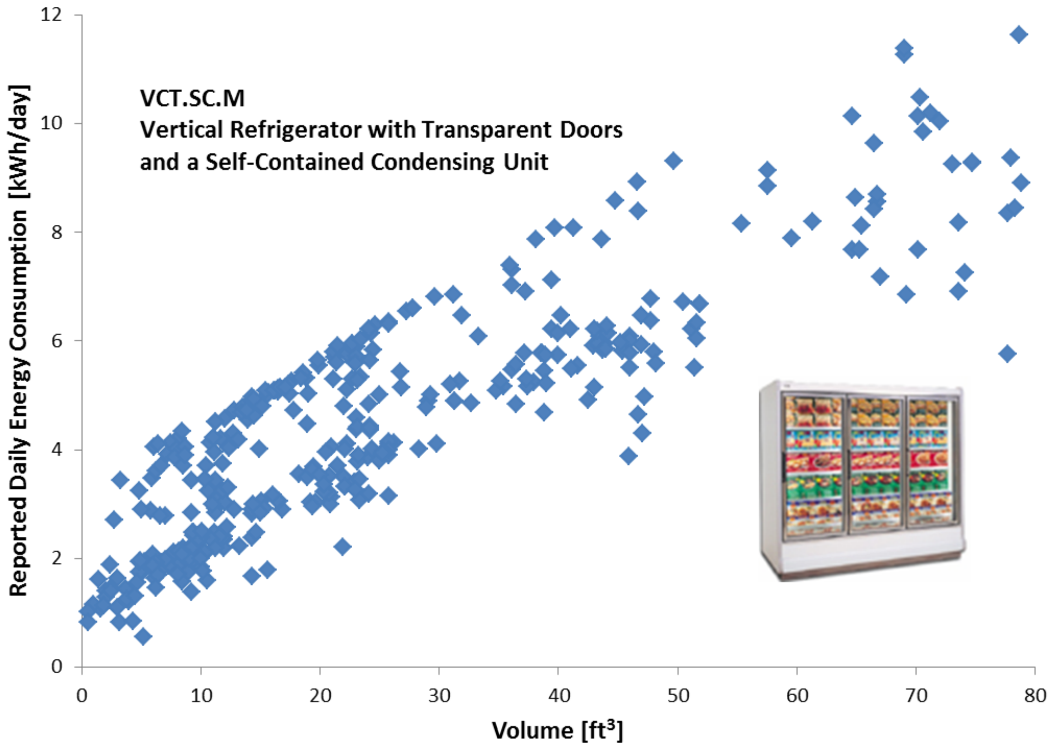


Figure 3.2.4 Market Performance Data for the VCT.SC.M Equipment Class

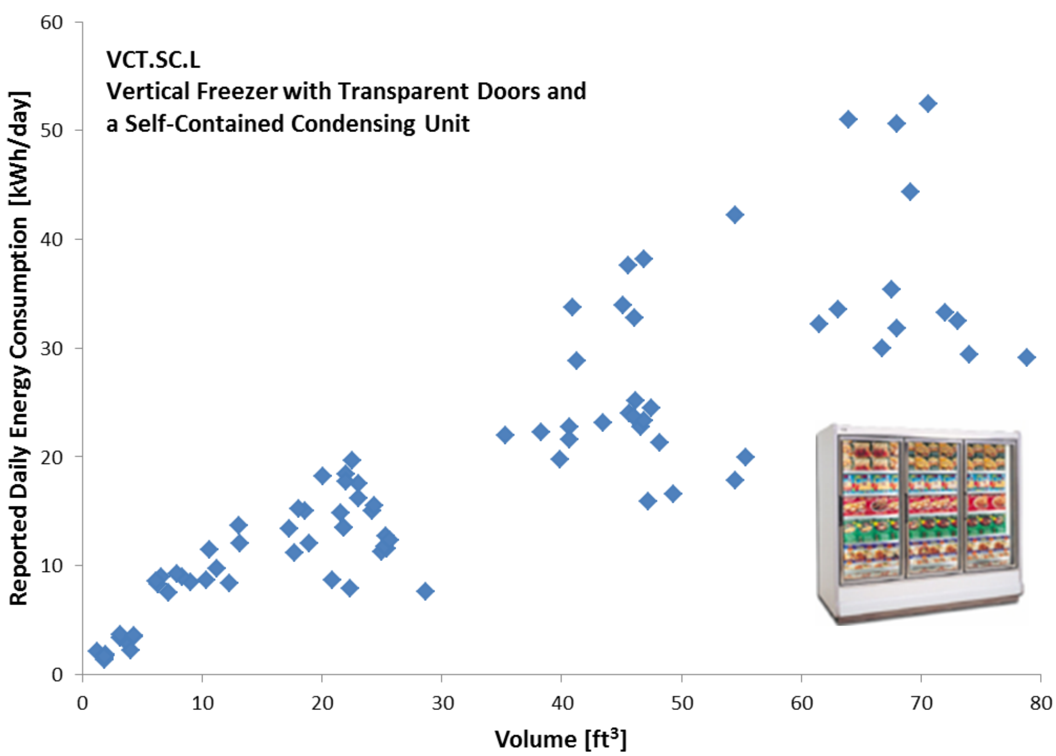


Figure 3.2.5 Market Performance Data for the VCT.SC.L Equipment Class

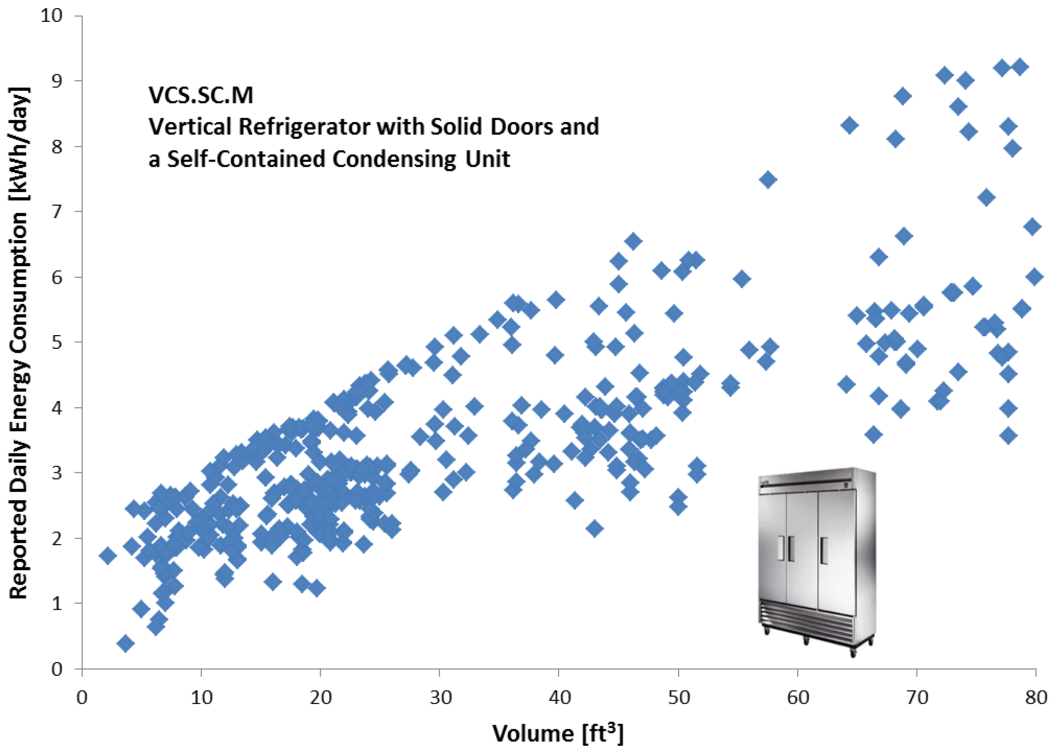


Figure 3.2.6 Market Performance Data for the VCS.SC.M Equipment Class

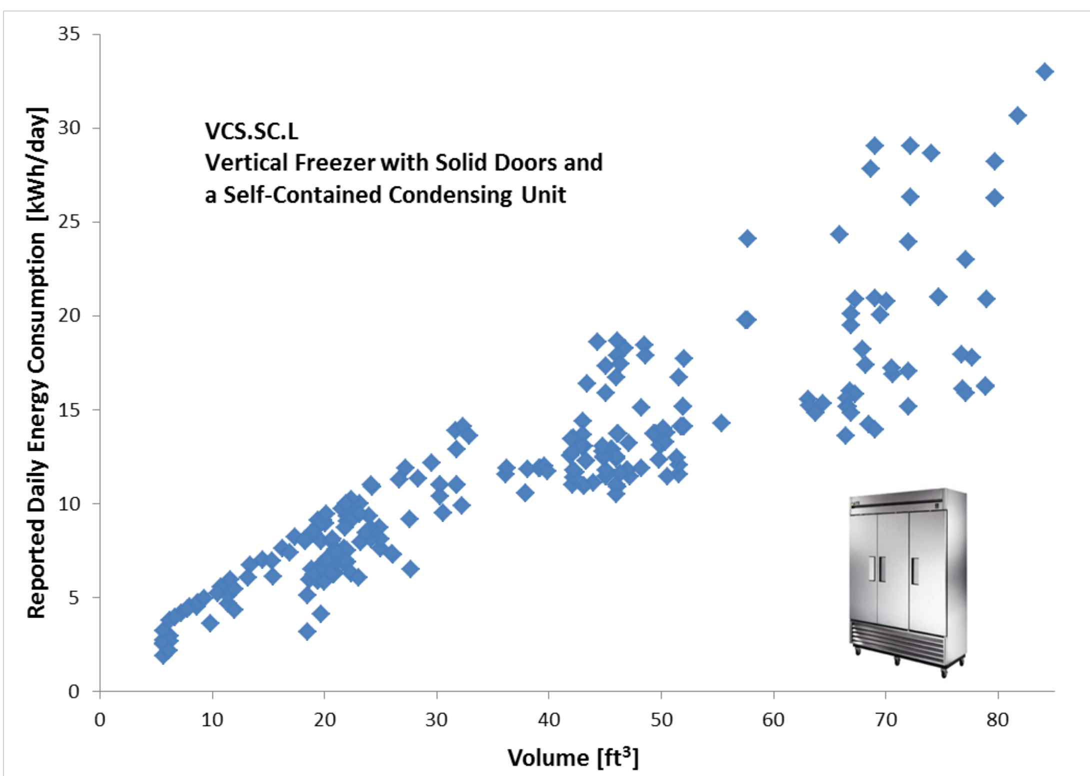


Figure 3.2.7 Market Performance Data for the VCS.SC.L Equipment Class

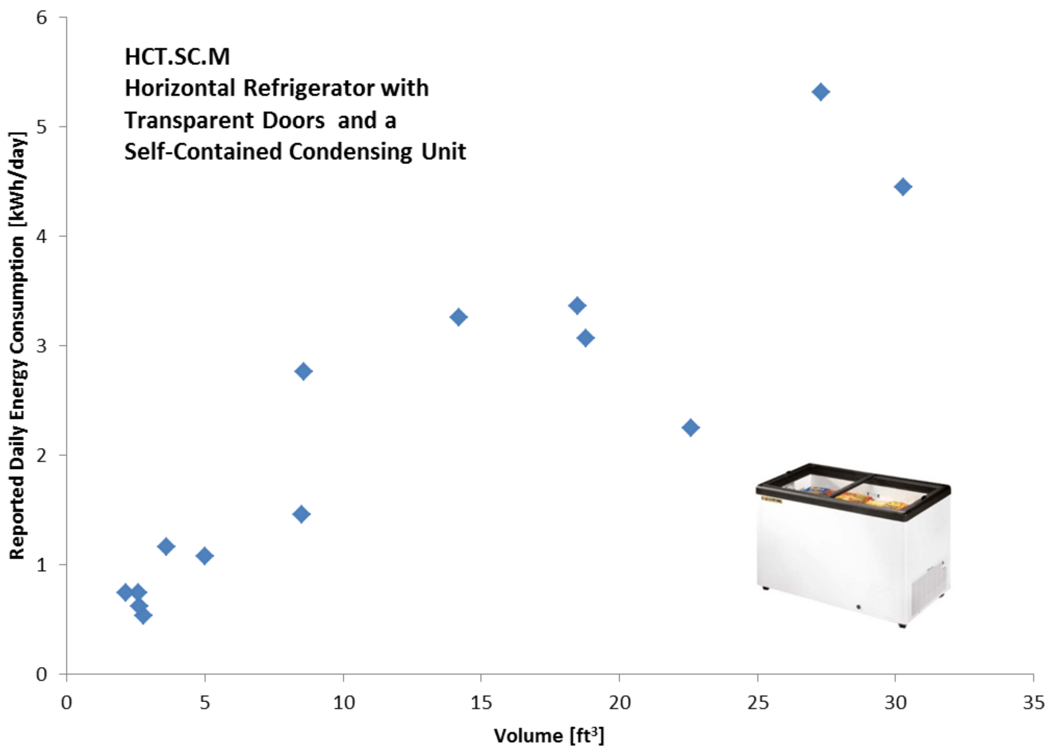


Figure 3.2.8 Market Performance Data for the HCT.SC.M Equipment Class

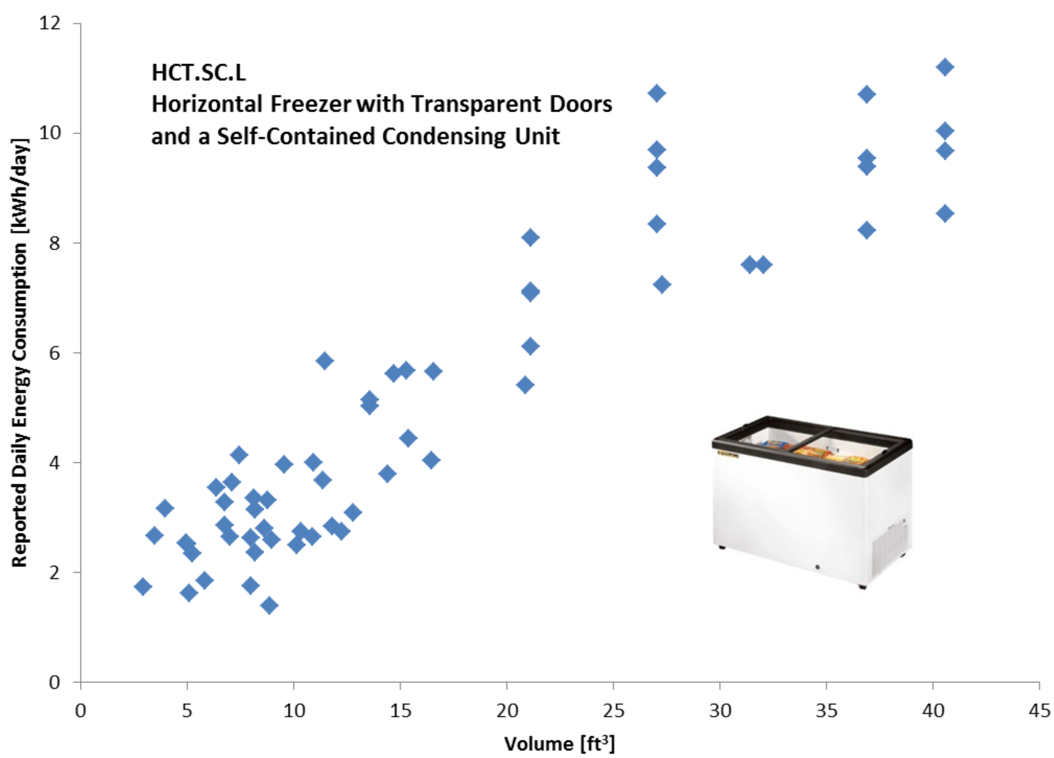


Figure 3.2.9 Market Performance Data for the HCT.SC.L Equipment Class

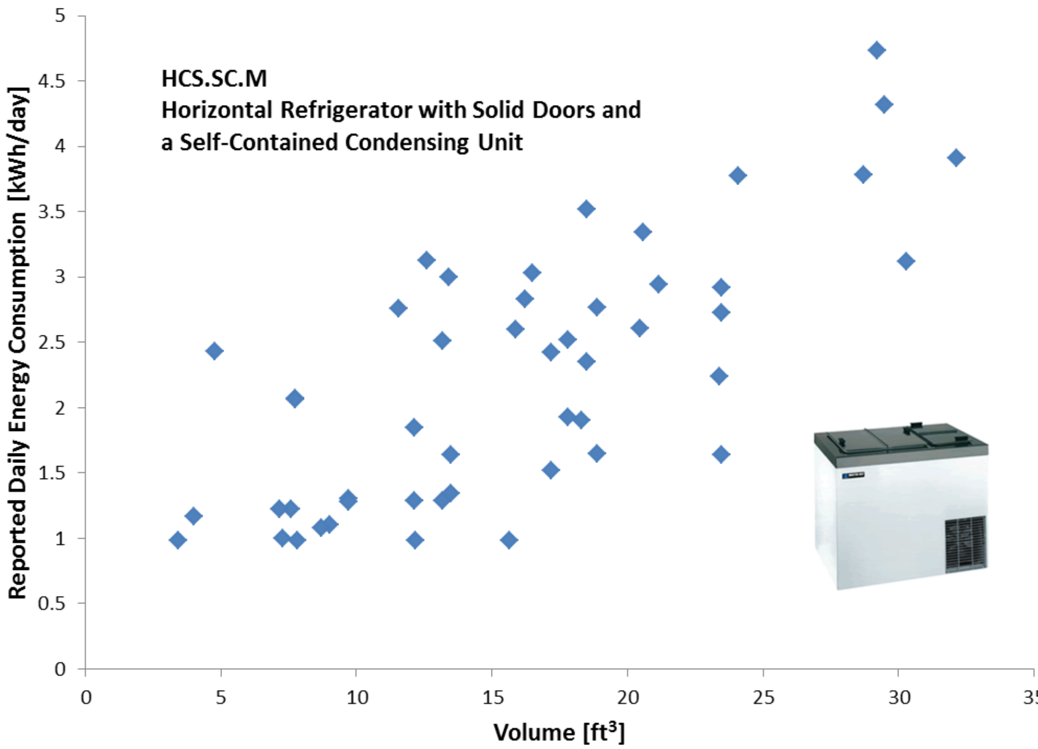


Figure 3.2.10 Market Performance Data for the HCS.SC.M Equipment Class

3.3 TECHNOLOGY ASSESSMENT

The purpose of the technology assessment is to develop a preliminary list of technologies that could potentially be used to improve the efficiency of commercial refrigeration equipment. The following assessment provides descriptions of technologies and designs that apply to all equipment classes; designs that apply to equipment without doors only; and technologies and designs that apply to self-contained equipment only.

3.3.1 Technologies and Designs Relevant to All Equipment Classes

The following technologies and designs are relevant to all equipment classes: higher efficiency lighting, higher efficiency lighting ballasts, remote ballast location, higher efficiency expansion valves, higher efficiency evaporator fan motors, variable-speed evaporator fan motors and evaporator fan motor controllers, higher efficiency evaporator fan blades, improved evaporator coil design, low-pressure differential evaporators, insulation increases or improvements, defrost mechanisms, defrost cycle control, vacuum insulated panels (VIPs), and occupancy sensors for lighting controls.

3.3.1.1 Higher Efficiency Lighting

Commercial refrigeration equipment often includes lighting to illuminate the contents. Some commercial refrigeration equipment also includes an illuminated sign on the exterior of the unit. Higher efficiency lighting leads to energy savings in two ways: less energy is used directly for lighting, and less heat energy is dissipated into the refrigerated case by the lamp. Efficiency in lighting is commonly measured as efficacy (lumens/watt), or the quantity of light output (lumens) per electrical energy input (watts, W).

During the time frame of the 2009 rulemaking, DOE found that the commercial refrigeration industry had begun using T8 fluorescent lighting in most cases. T8 lighting is substantially more efficacious than T12 lighting and is predominantly used with electronic ballasts, which are more efficient than the magnetic ballasts commonly used in T12 lighting.

A significant trend in recent years has been the use of LED technology. Although LEDs currently on the market consume more energy per lumen of light output than fluorescents, they provide better directionality than linear fluorescent bulbs, allowing for greater control of the light output. The result is comparable product illumination with less total wattage. There have been recent advancements in LED efficacy and numerous large retailers have adopted LED technology. Research by the Lighting Resource Center indicates that consumers found lighting in display cases using LEDs desirable. [37] Every major display door manufacturer offers LED lighting as design option, and some are moving to make LEDs a standard feature on their doors.

3.3.1.2 Higher Efficiency Lighting Ballasts

Higher efficiency lighting ballasts reduce energy consumption by requiring less electrical power to operate and by reducing waste heat generation, which contributes to case heat load.

Many illuminated display cases currently installed in supermarkets use fluorescent lighting with magnetic ballasts, which use inductance to modulate power flow to fluorescent lamps. Magnetic ballasts have significant electrical resistance losses. More recently, the market has moved toward the use of electronic ballasts, which use solid state electronics to modulate the power provided to fluorescent lamps. Electronic ballasts, which convert power at high frequency, have lower electrical resistance losses compared to magnetic ballasts, which operate at line frequency. Fluorescent lamps also operate more efficiently at the higher frequency provided by electronic ballasts. In addition to the direct reductions in electrical power consumption, heat generated by the lighting and the lighting ballast contribute to the case heat load, as both the lighting and ballasts are often located inside the refrigerated space. Increasing ballast efficiency also reduces the case heat load, and thus the compressor load. DOE notes that LED lighting does not require independent lighting ballasts, as the LED emitters generally are powered by onboard drivers built into each fixture.

3.3.1.3 Remote Lighting Ballast Location

Because ballasts may be located apart from the fluorescent lamps they power, manufacturers could choose to place them within the display case cabinet but outside of the refrigerated space, reducing heat load and case energy consumption.

3.3.1.4 Higher Efficiency Expansion Valves

Expansion valves are refrigerant metering devices that control the amount of refrigerant flowing to the evaporator coil. In doing so, they simultaneously decrease the temperature and pressure of the refrigerant, creating a cold liquid-vapor mixture. The low temperature of the refrigerant leaving the expansion valve creates the driving force to move heat out of the refrigerated space and into the evaporator.

The most basic type of expansion device is a capillary tube, which may be found in small self-contained commercial refrigeration equipment. The capillary tube is a long, thin piece of pipe that creates a pressure drop in the refrigerant through frictional losses. Capillary tubes must be sized to the particular application and cannot adjust for variations in load or ambient operating conditions. They are often oversized for worst-case conditions, and therefore may operate at reduced efficiency during normal operation.

The thermostatic expansion valve (TXV) is common in remote condensing commercial refrigeration equipment. This device uses an orifice to reduce the pressure of the entering refrigerant and a sensing bulb to monitor and maintain the temperature of the superheated vapor leaving the evaporator. Because the TXV allows for some degree of adjustment of refrigerant expansion, it may be somewhat more efficient than the capillary tube device under varying conditions.

The electronic expansion valve (EEV) is similar to the TXV, but uses an electronic control system to optimize refrigeration-system performance under all operating conditions. Because it does this with greater flexibility than a TXV allows, an EEV theoretically allows for increases in energy efficiency under varying conditions. However, as with the TXV, an EEV will likely not provide significant energy savings over a properly sized capillary tube or a TXV under fixed ambient conditions such as those used in the DOE test procedure.

3.3.1.5 Higher Efficiency Evaporator Fan Motors

Evaporator fan motors are fractional horsepower in size (generally on the order of 6-12 watts), are responsible for moving air across the evaporator coil, and typically run at one speed. The manufacturer will match the motor size and blade design to the evaporator coil to meet the expected load on the case under most conditions. Higher efficiency evaporator fan motors reduce energy consumption by requiring less electrical power to generate motor shaft output power.

Electric motors operate based on the interaction between a field magnet and a magnetic rotor. In a brushed motor, the field magnets are permanent magnets and the rotor is an electromagnet; the situation is reversed in a brushless motor. The electromagnetic interactions between these two magnets cause the rotor to rotate.

Single-phase motors, the simplest type of electric motor, suffer from a serious shortcoming. Single-phase motors only produce a rotating magnetic field when the rotor is rotating, and simply powering the electromagnet is therefore not sufficient to start such a motor. One of the most significant differences between different types of single-phase motors is the way in which they handle this start-up problem.

Nearly all inexpensive fan motors are either shaded-pole or permanent split capacitor (PSC), and the same is true for baseline commercial refrigeration equipment fan motors (fan motors not marketed as "high efficiency"). In both cases, the electromagnet consists of windings of electrical wire through which current is driven. In a shaded-pole motor, a portion of these windings is "shaded" by a copper loop. The interactions between the magnetic field generated by the shaded portion and that generated by the unshaded portion induce rotation when the motor is powered. Because the imbalance between the shaded and un-shaded portions of the magnet remains throughout operation, however, shaded-pole motors are inefficient, with typical motor efficiencies less than 20 percent.[38] Shaded-pole motors are, however, electrically simple and inexpensive.

In a PSC motor, a smaller, start-up winding is present in addition to the main winding. The start-up winding is electrically connected in parallel with the main winding and in series with a capacitor. At start up, the interactions between the magnetic field generated by the start-up winding and that generated by the main winding induce rotation. Because of the capacitor, however, the current to the start-up winding is cut off as the motor reaches steady state. Due to this design, PSC motors are more energy efficient than their shaded-pole counterparts, with motor efficiencies ranging from 25 to 40 percent, according to DOE's research, depending on motor size, design, and manufacturer. The energy efficiency of commercial refrigeration equipment fans that use shaded-pole motors can be substantially improved by replacing them with PSC motors.

A third type of electric motor, the ECM motor (also known as the brushless permanent magnet motor), is more energy efficient than both shaded-pole and PSC motors. ECM motors, which are sold in high volumes, are three-phase electric motors with efficiencies even greater than PSC motors. These motors are actually DC motors, often with a built-in inverter allowing them to run off of AC current. They also feature a permanent magnet rotor. An electronic controller pulses power to the motor, and these signals drive different groups of windings inside the motor. The controller modulates these pulses of power in order to maintain a desired speed and torque output. The result is a motor that is capable of maintaining constant torque and of varying its speed as needed, resulting in high operating efficiencies, on the order of 60–70 percent at the sizes used in commercial refrigeration equipment. However, ECM motors can weigh about twice as much and are more expensive than equivalent PSC motors.

3.3.1.6 Variable-Speed Evaporator Fan Motors and Evaporator Fan Motor Controllers

Evaporator fan motor controllers allow fan motors to run at variable speed to match changing conditions in the case. During periods of frost build-up, fan motor power requirements increase; during the post-defrost period, power requirements decrease. Evaporator fan speeds could also be modulated to account for increased or decreased refrigeration load due to product loading, ambient conditions, or other factors. Varying the fan speed to suit the conditions could ensure more stable discharge air temperatures (and thus more stable product temperatures) and improve coil performance. Evaporator fan motor controllers could also allow the case to run more efficiently at different ambient humidity and temperature levels.

3.3.1.7 Higher Efficiency Evaporator Fan Blades

High-efficiency evaporator fan blades, or tangential evaporator fans, move air more efficiently, yielding energy consumption savings by reducing the required fan shaft power. The evaporator fans typically used in commercial refrigeration equipment have sheet metal blades. Usually, the fan blade manufacturer supplies the blades and the equipment manufacturer mounts them. These fan blades are not optimized for commercial refrigeration equipment. Evaporator fans may have lower efficiencies due to the higher required pressure drops, for which sheet metal fans are not well suited. Required fan shaft power could be reduced if the fan blades were optimized for each application.

Tangential fans are one technology that provide an opportunity to decrease equipment energy consumption.[39] Tangential fans use a vortex builder to generate a uniform airflow over a large surface. This makes them better suited to evaporator and condenser fans, which need to distribute airflow over a large coil surface area. A single long tangential fan can meet the airflow requirements for an entire refrigerated cabinet, and would require only one high-efficiency fan motor.

3.3.1.8 Improved Evaporator Coil Design

The evaporator is a refrigerant-to-air heat exchanger composed of metals with high thermal conductivity such as aluminum and copper. It is responsible for evaporating and superheating the entering refrigerant liquid-vapor mixture while extracting heat from the air in the refrigerated space. The internal heat-exchanging surfaces in contact with refrigerant are commonly referred to as “refrigerant-side,” while the external heat-exchanging surfaces in contact with the air are referred to as “air-side.”

Depending on the requirements of the equipment, the evaporator can be designed to have a discharge air temperature (DAT) that can be up to 10 °F colder than the desired temperature of the refrigerated space. Because a temperature difference is necessary to drive heat into the refrigerant from the air passing over the coil, the saturated evaporator temperature (SET) must be considerably colder than the DAT. The magnitude of this driving force is directly related to the total refrigeration load and the thermal characteristics of the evaporator, as shown in Eq. 3.1.

$$DAT - SET = \Delta T = \frac{Q}{UA}$$

Eq. 3.1

Where:

Q = the total refrigeration load (Btu/h),
U = the heat transfer coefficient of the evaporator (Btu/°F/ft^2),
A = the area of the evaporator (ft^2), and
ΔT = the temperature difference between the discharge air temperature and evaporator temperature (°F).

Increasing the effective heat transfer surface area of the coil or improving other thermal characteristics of the coil will decrease the necessary ΔT and therefore decrease the SET. This results in an increased compressor energy efficiency ratio (EER) and lower compressor energy consumption.

Enhancements to the refrigerant-side surface area of the evaporator typically include rifled or diamond-pattern tubing and an increase in the number of tube passes. Enhancements to the air-side surface area can include increased fin pitch (decreased fin spacing), fin patterns (wavy or zig-zag), and increased numbers of tube passes.

Increasing the overall size of the coil in one or more dimensions without changing other aspects of the coil is another way to increase the area. However, many applications place limits on the feasible increase in the size of the coil.

3.3.1.9 Low-Pressure Differential Evaporators

Decreasing the air-side pressure drop of an evaporator coil allows for the use of lower power evaporator fan motors. This can be enabled through utilization of designs that reduce restrictions to the flow of air across the coil, such as reducing the fin pitch and decreasing the number of tube passes. Large spaces between fins and tubes also reduce "bridging" due to frost buildup, which can completely block airflow through portions of the coil.

3.3.1.10 Case Insulation Increases or Improvements

Either increasing the insulation thickness or reducing insulation conductivity will reduce the energy consumption of commercial refrigeration equipment. Typical baseline insulation thickness for refrigerated display cases ranges from 1.5 inches for medium-temperature units to 2.5 inches for ice-cream temperature units. This thickness also varies by manufacturer and model. Foamed-in-place polyurethane foam is used for most cases. Improved technology polyurethane foam insulation can reduce conductivity, and thus case heat load. The improvement is due mainly to the formation of smaller air cells within the foam insulation structure and better cell-size consistency. Additionally, a variety of blowing agents are available for use on the market, with different blowing agents resulting in different thermal properties for the foam produced. The impact of an increase in insulation thickness or insulation quality is generally limited for open cases because a large portion of the cooling load is due to infiltration. Cases with doors stand to gain more significant energy savings due to increased insulation thickness and/or quality.

3.3.1.11 Defrost Mechanisms

As the air in the refrigerated space is cooled, water vapor condenses on the surface of the evaporator coil. In refrigerators and freezers, where the evaporator coil is below 32 °F, this water freezes as it collects, forming a growing layer of frost. The frost reduces cooling performance by increasing the thermal resistance to heat transfer from the coil to the air, and by obstructing airflow. Both the method in which defrost is performed and control of the defrost cycle can lead to increased energy savings.

There are several methods available for defrosting the evaporator coil: off-cycle defrost, electric defrost, and hot-gas defrost. Off-cycle defrost involves shutting off refrigerant flow to the coil while leaving the evaporator fan running. This method is used where case air is above the freezing point of water and can be used to melt the frost. Electric defrost is used when the air temperature is not high enough to defrost the coil, and when defrost must occur quickly to prevent any significant rise in product temperature. Electric defrost involves melting frost by briefly turning on an electric resistance heater that is in contact with or near the evaporator coil.

Hot-gas defrost involves the use of the hot compressor discharge gas to warm the evaporator from the refrigerant side. Electricity usage is reduced in comparison to the electric defrost method because available heat, which would otherwise be rejected in the condenser, is used. The hot gas defrost system requires more complicated piping and control than electric defrost. An additional drawback is the thermal stress inflicted upon the refrigerant piping by the alternating flow of hot gas and cold refrigerant.

3.3.1.12 Defrost Cycle Control

Management of frost buildup on coils is essential in ensuring continued efficient operation of the unit. Traditionally, defrosting systems have been run on regular intervals utilizing a simple timer. However, such systems have two possible negative consequences in that the defroster may be run too often, resulting in wasted energy, or not often enough, resulting in decreased system performance. Some systems have been developed that allow for control of the termination of defrosting based on temperature; when the coils reach a specified temperature, the defroster is turned off. However, initiation of the cycle still occurs on a periodic basis using a timer.

Control of the defrost cycle requires the use of sensors to determine whether 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 across the coil will increase. However, there are issues in that external factors aside from frost buildup on the coil may be the reason for decreased airflow. The second method is more accurate but requires more sophisticated sensors. There has been significant research performed regarding the topic of defrost cycle control, and several manufacturers have introduced controllers that are now commercially available. However, due largely to concerns about reliability and accuracy, these technologies have not achieved large-scale acceptance in the commercial refrigeration equipment market.

3.3.1.13 Vacuum Insulated Panels

The importance of the amount of refrigerated volume that a unit offers and the desire to reduce unit energy consumption suggest that technologies that would allow an increase in insulation thermal resistivity (R-value) while maintaining insulation thickness would be of interest. VIPs could provide such performance. VIPs consist of an outer airtight membrane surrounding a core material to form a cavity, which is then evacuated to remove the air from the panel. The result is a product that performs in a manner similar to a traditional vacuum flask, resulting in greatly reduced thermal conduction per unit of thickness as compared to traditional foam insulations. VIP technology has existed for many years, but has only recently begun to see widespread application, most notably in residential refrigerators, due to decreasing production costs.

3.3.1.14 Occupancy Sensors for Lighting Controls

Lighting is one of the major sources of energy consumption in commercial refrigeration equipment. While higher efficiency lighting reduces the total lighting energy consumption, it could be decreased further by employing occupancy sensors to switch off or dim the display case lighting when not necessary, such as during periods of low customer traffic and when the store is closed. Occupancy sensors turn off or dim the case lighting when no motion is sensed near the case for a preset period of time.

Occupancy sensors are not used with fluorescent lighting due to restarting issues at low temperatures. However, LED lighting does not have such problems. Therefore, occupancy sensors can be used only in conjunction with LED lighting.

3.3.2 Designs Relevant Only to Equipment with Doors

The following technologies and designs are relevant only to equipment classes with doors: improved transparent doors, anti-fog films on transparent doors, and anti-sweat heater controllers.

3.3.2.1 Improved Transparent Doors

Transparent doors allow refrigerated products to be displayed to consumers while keeping cold air inside the display case. Transparent doors also generally have a lower thermal resistance than solid insulated walls, thus allowing heat transfer into the refrigerated space at a higher rate. In cases with transparent doors, these surfaces are responsible for a significant portion of the case heat load. On freezers and some refrigerators, glass doors must also be heated to prevent frost or condensation from forming on the outside. These “anti-sweat” heaters often run continuously and consume significant amounts of energy, and also contribute to the case heat load. Total case energy consumption can be reduced both by improving the overall insulation value (U-factor) of the door and by reducing the required anti-sweat heater power. Improvements to 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. The treatment of the window glass with advanced low emissivity coatings and increasing the number of coated surfaces could also reduce losses due to radiation heat transfer. Additionally, improvements to door frame insulation and gasketing would reduce conduction and infiltration losses. Reductions in the anti-sweat heater power needed can often be achieved as a function of improved conductive performance of the door, as well as in improvements to the gasketing and other door features. This is because the exterior surface of a better-insulated door will have a higher temperature than one with poor insulating properties, thus making condensation on the exterior of the door less likely.

3.3.2.2 Anti-Fog Films on Transparent Doors

Most commercial refrigeration equipment with transparent doors for merchandising and product access currently utilizes anti-sweat heaters to prevent fogging and condensation build-up. However, there are anti-fog treatments composed of advanced hydrophobic materials that prevent condensate from attaching or lingering on a glass surface and therefore prevent the formation of water droplets that may obscure a customer’s view of the product. Such anti-fog films could potentially be used on transparent doors as a static means of preventing fogging, eliminating the need for active energy-consuming systems.

3.3.2.3 Anti-Sweat Heater Controllers

Anti-sweat heater controllers match the run time of anti-sweat heaters to the anti-sweat heating requirements imposed by the ambient humidity, reducing energy consumption when ambient humidity is low. Anti-sweat heaters are used to prevent moisture condensation on surfaces of display cases, the temperatures of which can be below the ambient dew point.

Freezer-door gaskets are a typical example of such a surface. Anti-sweat heaters on freezer-door gaskets are typically always on, but the installation of controls that sense ambient conditions can turn off the heaters when anti-sweat heating is not required, reducing electricity consumption. Such control requires measuring the local dew point or relative humidity, and measuring external surface temperatures. A particular heater can be turned on when the temperature of a particular surface falls below the dew point, or the heaters can be cycled with on-times increasing with dew point. Reducing anti-sweat heater on-time will also yield additional energy savings in display-case heat load reductions, since anti-sweat heaters contribute to case heat load.

It is possible that electric anti-sweat heaters could be replaced by a hot gas line running around the door frame. Although manufacturers have claimed that this is a difficult technology to implement, it has seen widespread and successful use in residential freezers.

3.3.3 Designs Relevant Only to Equipment Without Doors

The following technologies and designs are relevant only to equipment classes without doors: air curtain design and night curtains.

3.3.3.1 Air Curtain Design

Refrigerated display cases without doors allow consumers easy access to products while maintaining temperatures that ensure food safety. In the absence of doors, a circulated air curtain is used to prevent infiltration and keep cold air inside the case. The refrigeration load for these cases is dominated by infiltration, or the entrainment of warm and moist air into the curtain. This infiltration adds both sensible and latent heat to the case, and deposits additional moisture on the evaporator coil, which must be removed through defrosting.

Improved air curtain design is aimed at lessening the impact of infiltration by reducing the entrainment of warm ambient air. Making the air curtain flow as laminar as possible reduces entrainment. This involves configuring the plenum before the air curtain discharge grill to shape the velocity profile using a honeycomb grill to align the airstreams and encourage laminar flow. Improvements to the velocity profile and discharge air grill may enhance the performance of the air curtain and reduce the infiltration load.

3.3.3.2 Night Curtains

Open display cases have a high rate of infiltration of warm external air into the refrigerated cases. During store operating hours, when the refrigerated products are being taken out by customers and restocked by staff, such infiltration losses are inevitable. However, infiltration could be substantially reduced during the hours when the store is closed by using infiltration reduction mechanisms called night curtains. Night curtains typically take the form of a flexible barrier, often composed of plastic or metalized fabric, which can be pulled down over the open case and fastened to provide a temporary cover over the opening. These devices reduce the heat and moisture entry into the refrigerated space through various heat transfer mechanisms. By fully or partially covering the case opening, night curtains reduce the convective heat transfer into the case through reduced air infiltration. Additionally, they provide a measure of insulation, reducing conduction into the case, and also decrease radiation into the case by blocking radiated heat from entering the refrigerated space.

3.3.4 Technologies and Designs Relevant Only to Self-Contained Equipment

The following technologies and designs are relevant only to self-contained equipment: higher efficiency compressors, liquid suction heat exchangers, improved condenser coil design, higher efficiency condenser fan motors, variable-speed condenser fan motors and condenser fan motor controllers, and higher efficiency condenser fan blades.

3.3.4.1 Higher Efficiency Compressors

Several technologies exist to increase the efficiency of commercial refrigeration equipment compressors. High-efficiency reciprocating and scroll compressors, sometimes incorporating variable-speed motors, all have the potential to reduce energy consumption compared to the traditional reciprocating compressors commonly used in commercial refrigeration equipment.

Scroll compressors compress gas between two spirals, one fixed and one rotating. This method is fundamentally different from that of traditional compressors. High-efficiency reciprocating compressors are as efficient, or more efficient, than scroll compressors. However, when compared to scroll compressors, some drawbacks exist to the use of high-efficiency reciprocating compressors, including noise, cost, and reliability.

Variable-speed compressors are implemented through an electronic control on the compressor motor, which allows the motor to operate at different speeds. Variable-speed compressors reduce energy consumption in three ways:[e]

1. When refrigerant flow is reduced during part-load operation, the condenser and evaporator (designed for full flow conditions) are more effective and thus more efficient. Temperature drops decrease, resulting in reduced pressure rise across the compressor, which also improves efficiency.

2. Close matching of load eliminates the cycling that occurs with single-stage compressors. Maintaining a constant pressure is more efficient because losses at higher pressure rise are greater than gains at lower pressure rise.

3. During the off cycle, the pressure in the system equilibrates. At intermediate pressure, refrigerant vapor will condense in the cold evaporator rather than the condenser.

[e] Variable-speed compressors typically increase efficiency over a broad operating range but do not inherently increase maximum efficiency at the compressor rating point

> Essentially, some of the heat rejection load is rejected to the evaporator during this time, reducing overall system performance. Variable-speed operation would eliminate or significantly reduce compressor off-time and the related inefficiencies.

However, scroll and variable-speed compressor technologies have not become present in the domestic commercial refrigeration equipment market on a significant scale, and DOE's research has indicated that a significant amount of research and development work would be required before these technologies could reach the market. Instead, commercial refrigeration equipment manufacturers often rely on compressor manufacturers to continuously update their designs for traditional reciprocating compressors. As updated models of reciprocating compressors, usually featuring higher efficiencies than the models they replace, appear on the market, these models are generally incorporated into the equipment offerings of the commercial refrigeration unit manufacturers.

3.3.4.2 Liquid Suction Heat Exchangers

The goal of a liquid suction heat exchanger is to further cool the flow of liquid refrigerant entering the expansion valve using the flow of gaseous refrigerant leaving the evaporator. The exchanger provides sub-cooling for the entering liquid by super-heating the exiting suction vapor. Hotter suction vapor is less susceptible to heat gains in the return piping to the compressor rack. The compressor work is increased, however, because the suction vapor has greater enthalpy. In addition, the possibility of compressor overheating problems brought on by the combination of increased compressor work and hotter vapor limits the use of this method in some situations. The possibility for these problems and the potential efficiency gains from liquid suction heat exchangers depend on several factors, including evaporator temperature, type of refrigerant used, and system pressures. Additionally, some parties have expressed concern regarding the reliability of liquid suction heat exchangers.

3.3.4.3 Improved Condenser Coil Design

Like the evaporator, the condenser is a refrigerant-to-air heat exchanger composed of metals with high thermal conductivity, such as aluminum and copper. It is responsible for condensing and sub-cooling the entering refrigerant vapor while rejecting heat from the refrigerant into the ambient air.

The condenser's saturated condenser temperature (SCT) is markedly warmer than the ambient air, with the exact temperature differential being a function of the equipment design and operating conditions. As with evaporator coils, increasing the area of the condenser coil or otherwise improving its heat transfer capability will decrease the necessary ΔT across the coil and therefore decrease the SCT, resulting in increased compressor efficiency (and thus increased EER).

Enhancements to the refrigerant-side surface area of the condenser typically include rifled or diamond-pattern tubing and an increase in the number of tube passes. Enhancements to the air-side surface area can include increased fin pitch (decreased fin spacing), fin patterns (wavy or zig-zag), and increased numbers of tube passes.

Increasing the overall size of the coil in one or more dimensions without changing other aspects of the coil is another way to increase the area. However, many applications place limits on the feasible increase in the size of the coil.

3.3.4.4 Higher Efficiency Condenser Fan Motors

Condenser fan motors are responsible for moving air across the condenser coil and typically run at one speed. The manufacturer matches the motor size and blade to the condenser coil to meet the expected load on the case under most conditions. Higher efficiency condenser fan motors reduce energy consumption by requiring less electrical power to generate motor shaft output power. Condenser fan motors are generally of the same size and type as evaporator fan motors. See section 3.3.1.5 for a discussion of higher efficiency fan motor technology.

3.3.4.5 Variable-Speed Condenser Fan Motors and Condenser Fan Motor Controllers

Condenser fan motor controllers could allow fan motors to run at variable speed to match changing conditions in the case. Matching the fan speed to varying conditions and heat loads could then improve system performance, allowing the refrigeration system to run more efficiently at different ambient humidity and temperature levels. However, under constant ambient conditions, the energy savings benefit with condenser fan motor controllers would likely be small.

3.3.4.6 Higher Efficiency 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 in order to minimize production cost and waste. Optimization of fan design for specific applications could significantly reduce input energy needed in order to perform the necessary work. Higher efficiency fan blades could be capable of moving more air at a given rotational speed when compared to traditional fan blades. This means that a smaller motor could be used, or the existing motor could be run at a lower speed, resulting in direct energy savings.

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CHAPTER 4. SCREENING ANALYSIS

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CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter describes the screening analysis that the U.S. Department of Energy (DOE) has performed in support of the energy conservation standards rulemaking for commercial refrigeration equipment.

In the market and technology assessment (chapter 3 of this technical support document (TSD)), DOE presented an initial list of technologies that have the potential to reduce the energy consumption of commercial refrigeration equipment. The goal of the screening analysis is to screen out technologies that will not be considered further in the rulemaking analyses. DOE evaluated the list of 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)) In addition, EPCA 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 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 inapplicable 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 in determining 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.

Impacts on equipment utility or equipment availability. If DOE determines that a technology will have significant adverse impact on the utility of the equipment to significant subgroups of consumers, or 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, DOE will not consider it further.

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

In summary, if DOE determines that a technology, or a combination of technologies, has unacceptable effects on the policies stated in section 5(b) of the Process Rule, it will be eliminated from consideration. If a particular technology fails to meet one or more of the four criteria, it will be screened out. The reasons for eliminating any technology are documented in section 4.3.

4.2 TECHNOLOGIES THAT DO NOT CONSISTENTLY AFFECT CALCULATED DAILY ENERGY CONSUMPTION

DOE understands that some of the technologies presented in chapter 3 of this TSD may potentially reduce annual energy consumption for specific pieces of equipment under certain field operating conditions, but may not consistently reduce calculated daily energy consumption (CDEC), as measured by the DOE test procedure, utilizing the American National Standards Institute/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ANSI/ASHRAE) Standard 72, *Method of Testing Commercial Refrigerators and Freezers*, for all units of a given class. In some cases, while a technology may benefit a specific individual model or unit produced by a given manufacturer, it may not necessarily be considered to have similar effects across all units of that same equipment class, depending on the design of each unit. Moreover, certain technologies may provide benefits within specific operating conditions that they may encounter in some field applications, but would not produce benefits within the scope of the ASHRAE method of test. Therefore, DOE removed from consideration those technologies that cannot be considered to consistently affect or reduce CDEC during the tests across the range of equipment analyzed. These technologies include higher efficiency expansion valves, variable-speed condenser fans and condenser fan motor controllers, anti-sweat heater controllers, and liquid-suction heat exchangers (LSHXs).

4.2.1 Higher Efficiency Expansion Valves

Higher efficiency expansion valves can reduce the annual energy consumption in some commercial refrigeration units by controlling refrigerant flow to adapt to varying loads and ambient conditions. However, this is largely a function of the design of a specific unit. While some models may benefit from the use of a higher efficiency expansion valve, others may not see the same efficiency increase due to a refrigeration system being configured differently. Moreover, while there are small thermodynamic fluctuations during the ASHRAE 72 test, the test as a whole is conducted under ambient and internal conditions that are held as close to constant as possible. Much of the advantage in the field performance of improved expansion valves arises from their ability to adapt to extreme variations in conditions, which are not likely to be experienced during the ASHRAE 72 test. Therefore, since this technology could not be found to have a consistent efficiency improvement effect across entire equipment classes, DOE did not consider higher efficiency expansion valves in the engineering analysis.

4.2.2 Variable-Speed Condenser Fans and Condenser Fan Motor Controllers

Variable-speed condenser fan motors and controllers driving the condenser fan motors can adapt condenser operation to changing ambient temperatures (effectively by creating floating head pressure), and thereby could reduce the energy consumption of self-contained commercial refrigeration equipment operating in areas with varying ambient conditions. However, because testing under the ANSI/ASHRAE Standard 72 test procedure is conducted at a constant ambient temperature, there is little opportunity to account for the adaptive technology of varying condenser fan motor speed to reduce CDEC. Moreover, DOE understands that condenser fan motor controllers would function best when paired with a variable-speed modulating compressor, a technology that DOE understands to be only in the early research and development stages of implementation in this industry. Therefore, DOE did not consider variable-speed condenser fan motors or condenser fan motor controllers in the engineering analysis.

4.2.3 Anti-Sweat Heater Controllers

A commercial refrigeration equipment manufacturer typically sizes anti-sweat heaters according to the ambient temperature and humidity of a particular operating environment. The end-user must maintain that environment to prevent condensation (*i.e.,* fog) from forming on surfaces such as display case glass. Anti-sweat heater controllers modulate the operation of anti-sweat heaters by reducing anti-sweat heater power when humidity is low. Anti-sweat heater controllers operate most effectively when a constant ambient dew point cannot be maintained. However, in the context of the test procedure, anti-sweat heater controllers will solely serve to keep the power to the anti-sweat heaters at the levels necessary for the test conditions. These fixed conditions of 75 °F and 55 percent relative humidity are the conditions that ASHRAE has determined to be generally representative of commercial refrigeration equipment operating environments and which DOE has adopted in its test procedure. While anti-sweat heater controllers could modulate the anti-sweat power to a further extent in the field so as to account for more or less extreme ambient conditions, a system equipped with anti-sweat heater controllers will not likely exhibit significantly different performance at test procedure conditions than a unit with anti-sweat heaters tuned for constant 75/55 conditions. Therefore, DOE did not consider anti-sweat heater controllers in the engineering analysis.

4.2.4 Liquid-Suction Heat Exchangers

An LSHX is an indirect liquid-to-vapor heat transfer device that evaporates any residual liquid refrigerant that remains in the evaporator discharge line, and thereby minimizes the risk of liquid refrigerant carrying over into the compressor. Generally, LSHXs are installed in refrigeration systems to ensure proper system operation and increase system performance. However, the performance of an LSHX is dependent on the specific design used in a given piece of equipment, as well as other properties of the system and the operating conditions. A combination of refrigerant type, operating temperature, ambient conditions, and other factors determines whether an LSHX will increase or decrease the CDEC as measured by the ANSI/ASHRAE Standard 72 test procedure. In some cases, an LSHX can produce enough of a pressure differential across the device, which requires additional compressor energy to overcome, that the result is a net increase in energy consumption. Manufacturers have stated that, while an LSHX can reduce energy consumption in a lower efficiency or baseline system, these devices often produce negative energy impacts in more advanced equipment designs. DOE has also heard from stakeholders that LSHXs may have issues with unreliability, resulting in refrigerant leakage and increased system energy consumption. Because LSHXs do not consistently reduce CDEC in the equipment classes analyzed, DOE did not consider this technology in the engineering analysis.

4.3 SCREENED-OUT TECHNOLOGY – AIR CURTAIN DESIGN

An air curtain is a fan-powered device that creates a moving wall (curtain) of air, which separates two spaces of different temperatures. Air curtains are used in commercial refrigeration equipment to minimize the infiltration of warmer external air into the refrigerated space. In its market and technology assessment (TSD chapter 3), DOE noted that its research had presented the possibility of advanced air curtain designs with levels of performance beyond the traditional air curtains generally employed in open display cases being used in the commercial refrigeration equipment industry. However, DOE has determined that advanced air curtain designs are only in the research stage and, therefore, it would be impracticable to manufacture, install, and service this technology on the scale necessary to serve the relevant market at the time the standard becomes effective. Sections 4(a) and 5(b) of the Process Rule specifically set "practicability to manufacture, install, and service" as a criterion that should be satisfied for technology to be considered as a design option. Therefore, DOE screened out improved air curtains as a design option for improving the energy efficiency of commercial refrigeration equipment.

4.4 REMAINING TECHNOLOGIES

After eliminating those technologies that do not reduce CDEC and screening out technologies that do not meet the requirements of sections 4(a)(4) and 5(b) of the Process Rule, DOE is considering the following technologies:

- higher efficiency lighting
- higher efficiency lighting ballasts
- remote lighting ballast location
- higher efficiency evaporator fan motors
- variable-speed evaporator fan motors and evaporator fan motor controllers
- improved evaporator coil design
- higher efficiency evaporator fan blades
- low-pressure differential evaporators
- case insulation increases or improvements
- defrost mechanisms
- defrost cycle controls
- vacuum insulated panels
- occupancy sensors for lighting controls
- improved transparent doors (equipment with doors only)
- anti-fog films on transparent doors (equipment with doors only)
- night curtains (equipment without doors only)
- higher efficiency compressors (self-contained equipment only)
- improved condenser coil design (self-contained equipment only)

- higher efficiency condenser fan motors (self-contained equipment only)
- higher efficiency condenser fan blades (self-contained equipment only)

CHAPTER 5. ENGINEERING ANALYSIS

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CHAPTER 5. ENGINEERING ANALYSIS

5.1 INTRODUCTION

The engineering analysis establishes the relationship between manufacturer selling price (MSP) and energy consumption for the commercial refrigeration equipment directly examined in this rulemaking. This equipment includes self-contained and remote condensing commercial refrigerators, freezers, refrigerator-freezers, and ice cream freezers, as well as self-contained commercial refrigerators with transparent doors designed for pull-down temperature applications. The "cost-efficiency" relationship, which depicts a manufacturer's cost of achieving increased equipment efficiency for a given equipment class, serves as the basis for downstream cost-benefit calculations with respect to individual customers, manufacturers, and the nation.

5.2 METHODOLOGY OVERVIEW

This section describes the analytical methodology that the U.S. Department of Energy (DOE) used for the engineering analysis. In this rulemaking, DOE adopted a design option approach to produce analytically derived curves depicting the cost-efficiency relationship for each equipment class analyzed. In a design option approach, the goal of the analysis is to calculate the incremental cost and energy consumption impacts of implementing specific energy-saving technologies, known as "design options," in a representative baseline design for a given equipment type.

To implement the design option analysis in this rulemaking, DOE first selected specific classes of covered equipment for which to quantitatively calculate the manufacturing cost and daily energy consumption directly (section 5.3.1). DOE analytically developed cost-efficiency relationships only for equipment classes with high shipment volumes, henceforth referred to as "primary" equipment classes. Some equipment classes were not included in the direct engineering analysis because they had low shipments volumes. These are referred to as "secondary" equipment classes. For each primary equipment class, a "representative" unit, intended to physically approximate a typical high-shipment-volume design currently on the market, was defined using sets of baseline parameters and specifications gathered from market research, industry publications, and manufacturer interviews (sections 5.3.2 and 5.5.2). This representative unit served as the point of analysis for the modeling of the equipment class that it represented. Baseline parameters were selected to represent the typical suite of technologies with which entry-level commercial refrigeration units available on the market at the time of this analysis were equipped. These parameters included specific physical attributes such as case volume, number of fans, and standard wall thickness.

In order to explore the efficiency improvements available for use with the equipment analyzed, DOE conducted research into energy-saving technologies applicable for implementation into commercial refrigeration equipment. This research, performed using sources including manufacturer interviews and reviews of trade literature, is summarized in chapter 3 of this technical support document (TSD), Market and Technology Assessment. The results of that analysis, a set of technology options, were compared against a set of screening criteria as described in TSD chapter 4, Screening Analysis. The outputs of the screening analysis were considered in the engineering analysis, and it was from these technologies that design options were selected for quantitative modeling (sections 5.6.3–5.6.5).

For each equipment class analyzed, DOE developed estimates of the cost to manufacture the representative unit at the baseline and higher efficiencies. In order to facilitate this, DOE developed estimates of the manufacturer production cost (MPC) of the unit at each design option level. DOE estimated two separate sets of costs in the analysis. The first of these was the cost to manufacture the refrigerated case of each representative unit. This "core case" consisted of components, such as structural members, shelving, wiring, air curtain grilles, and trim, that did not change at higher design option levels. Core case costs were developed through physical teardowns and cost modeling of equipment purchased on the market during the analysis period (section 5.4.1). The second set of cost data estimated the costs to manufacture and install the components that make up each design option. These were elements of the equipment, including heat exchangers, fans, glass doors, and lighting, that directly affected daily energy consumption and thus were manipulated in the engineering analysis. The costs for the design options were developed from a number of sources and corroborated with feedback from industry (section 5.4.2). Core case and design option costs were coupled to yield system MPCs for each representative unit at each level of efficiency modeled (section 5.4.3).

In order to calculate estimates of daily energy consumption for each representative unit at each design option level examined, DOE developed an analytical model to simulate the performance of each unit, as configured, when tested under the DOE test procedure. This model used the representative unit specifications, design option data (section 5.6.5), test procedure provisions, and a set of assumptions (sections 5.6.1 and 5.6.2) to produce estimates of daily energy consumption for each equipment configuration studied. To produce these estimates, the model calculated the heat load placed on the given piece of equipment by the ambient conditions and heat-producing internal components. The model selected an appropriately-sized remote condensing or self-contained compressor and then calculated the electrical input energy into the compressor required to remove the heat load during the simulated test period. The additional energy consumption during the test period of energy-consuming components such as fans, defrost heaters, and lighting was also calculated, summed, and added to the compressor energy consumption as applicable to yield estimates of daily electrical energy consumption for each equipment configuration modeled (section 5.6.6).

DOE organized the results of the energy consumption and cost models in the form of cost-efficiency curves for each equipment class analyzed, depicting MPC versus daily energy consumption. To form the curves, DOE ordered the design options and their associated cost and energy consumption data based on cost effectiveness, ranging from the baseline to the maximum technologically feasible ("max-tech") equipment configuration for each class. DOE then applied manufacturer markups and added outbound freight costs to the MPC estimates to express the relationship between MPC and MSP (section 5.5). The final result was a set of cost-efficiency curves comparing MSP and daily energy consumption at all modeled design option levels for each primary equipment class (section 5.7).

Energy conservation standards for the covered equipment classes take the form of linear equations expressed as a function of refrigerated volume or total display area and defined by a slope and y-intercept. These equations were developed using the outputs of the engineering analysis, with specific analysis points corresponding to calculated daily energy consumption (CDEC) values for each class. The engineering analysis contained an ancillary calculation necessary in developing standard-level equations for the covered equipment. Specifically, this calculation developed the y-intercept values, referred to in the January 2009 final rule analysis as "offset factors." These offset factors serve to represent energy consumption end effects inherent in equipment operation regardless of the size of the equipment, and originated out of stakeholder concerns during the 2009 rulemaking that standards based on a single analysis point could be insufficient to account for the energy consumption of smaller pieces of equipment. The offset factors prevent the allowable maximum energy use from going towards zero at small volume or total display area (TDA) values. Section 5.8 further explains the offset factor methodology that DOE used in developing its standard-level equations.

Another auxiliary analysis sought to develop standards for the secondary equipment classes that were not directly analyzed in the cost and energy consumption models. In the January 2009 final rule analysis, DOE developed standards for these equipment classes using energy-consumption conversion factors called "extension multipliers." These factors were developed using analytical correlations between energy-consumption values for sets of equipment classes with similar features. The extension multipliers were then applied to the standard-level equations developed for the primary classes to obtain standard-level equations for secondary classes. DOE adopted these same extension multipliers in developing standard-level equations for the notice of proposed rulemaking (NOPR) stage of this rulemaking; this methodology is explained in detail in section 5.9.

5.3 EQUIPMENT CLASSES ANALYZED

5.3.1 Classes Chosen for Analysis

In the Framework document, DOE provided a list of nomenclature consisting of 49 equipment class designations. This list includes the 38 equipment classes for which standards were set in the 2009 rulemaking, as well as 11 class designations for equipment covered by standards set in the Energy Policy Act of 2005 (EPACT 2005). In its analyses for the 2009 DOE final rule on commercial refrigeration equipment, DOE only analyzed 15 high-shipment-volume equipment classes ("primary" classes) and then extended the standards developed from those analyses to cover the remaining 23 equipment classes with smaller number of shipments ("secondary" classes). 74 FR 1092, 1121 (Jan. 9, 2009). Because DOE did not receive any comments or data indicating that there had been major changes in shipment patterns since the 2009 final rule or other reasons that would necessitate a change in the primary classes, DOE elected to retain the primary equipment classes from the 2009 rulemaking. DOE also directly analyzed 10 of the 11 classes consisting of equipment previously covered by the EPACT 2005 standards, with the exception of the SOC.SC.L class (a low-shipment-volume class that was treated as a secondary class). Combined with the 15 primary equipment classes from the 2009 final rule, the result is a total of 25 primary equipment classes that were directly analyzed in this engineering analysis and a total of 49 equipment classes for which DOE has proposed standards.

Table 5.3.1 shows the equipment classes for which amended standards are being considered in this rulemaking, organized by equipment family, condensing unit type, and rating temperature, and highlights the 25 primary equipment classes that DOE directly analyzed in the engineering analysis.

Table 5.3.1 Equipment Classes Analyzed in the Engineering Analysis

Equipment Family		Remote Condensing			Self-Contained		
		Medium	**Low**	**Ice Cream**	**Medium**	**Low**	**Ice Cream**
Without Doors	VOP	✓	✓	x	✓	x	x
	SVO	✓	x	x	✓	x	x
	HZO	✓	✓	x	✓	✓	x
With Doors	VCT	✓	✓	x	✓	✓	✓
	VCS	x	x	x	✓	✓	✓
	HCT	x	x	x	✓	✓	✓
	HCS	x	x	x	✓	✓	x
	SOC	✓	x	x	✓	*	x
	PD	**	**	**	✓	**	**

✓ Primary equipment class.
x Secondary equipment class
* Class not analyzed in this rulemaking; see section 5.3.3.
** Classes not covered in the rulemaking.

HCS = Horizontal Closed Solid.
HCT = Horizontal Closed Transparent.
HZO = Horizontal Open.
PD = Pull-Down.
SOC = Service Over Counter.
SVO = Semi-Vertical Open.
VCS = Vertical Closed Solid.
VCT = Vertical Closed Transparent.
VOP = Vertical Open.

The engineering analysis specifically considered refrigerators (medium temperature), freezers (low temperature), and ice-cream freezers (ice-cream temperature) individually, but it did not explicitly consider refrigerator-freezers (combinations of compartments at medium and low temperatures) directly. Instead, DOE plans to maintain the approach used in the 2009 final rule, in which DOE developed a method to combine the standards for refrigerators, freezers, and ice-cream freezers to create standards for refrigerator-freezers. Similarly, while the engineering analysis did not explicitly consider hybrid equipment, consisting of multiple compartments from different equipment families contained in a single unit, the 2009 final rule presented a methodology for combining standards to create standards for hybrid units. DOE intends to preserve that methodology for use with all of the equipment covered this rulemaking. The 2009 final rule *Federal Register* notice describes this methodology in detail. 74 FR 1092, 1122 (Jan. 9, 2009).

5.3.2 Baseline Equipment

For the engineering analysis, DOE modeled each primary class starting at a baseline design option level, increasing unit efficiency as design options were upgraded to higher technology levels. Baseline efficiencies were established by reviewing available manufacturer data regarding equipment available at the time of the analysis and selecting components and design features that were representative of the most basic, widely manufactured models being sold on the market. Due to the timing of this analysis, the units for sale on the market that DOE examined were not necessarily in compliance with the January 2009 final rule. This is because the January 2009 final rule standards had a compliance date of January 1, 2012, falling after the time frame for the NOPR engineering analysis. Therefore, DOE instead retained the baseline specifications and associated technologies used in the January 2009 final rule engineering analysis and expanded its sets of representative equipment specifications to include the equipment classes covered under standards established by the Energy Policy and Conservation Act (EPCA). DOE believes that this is the best approach to addressing the baseline for this equipment, because sufficient information on equipment compliant with the 2009 standards was not available at the time of the engineering analysis.

5.3.3 Service over Counter Equipment

In the preliminary analysis for this rulemaking, DOE chose not to include the SOC.SC.M equipment class in the engineering analysis because of ongoing issues with the standards set for that class by EPACT 2005. Standards prescribed in EPCA, as amended by EPACT 2005, for self-contained refrigerators and freezers with doors were based on the California Energy Commission Appliance Efficiency Regulations published in April 2005. (CEC-400-2005-012, section 1605.3) The California Energy Commission regulations set standards for "reach-in cabinets, pass-through cabinets, and roll-in or roll-through cabinets." However, EPCA does not explicitly outline such equipment subsets beyond defining the terms "commercial refrigerator, freezer, and refrigerator-freezer" and "self-contained condensing unit," among other definitions related to this equipment. These EPCA definitions resulted in the application of these standards to all self-contained refrigerators, freezers, and refrigerator-freezers, including SOC.SC.M.

In December 2009, DOE's Office of Hearings and Appeals (OHA) responded to an application for exception relief from a manufacturer of service over counter equipment. This manufacturer argued that it was entitled to relief because its service over counter units could not meet the EPACT 2005 standards for self-contained equipment with doors. OHA responded that DOE did not have jurisdiction to consider such exceptions for equipment covered by the statutorily mandated standards. (Case no. TEE-0066, Dec. 29, 2009)

In response to the concerns manufacturers expressed in comments at the Framework public meeting and in written comments, as part of its preliminary analysis for this rulemaking DOE compared the standards set for a specific type of service over counter units in the 2009 final rule, namely remote condensing medium-temperature units, with the EPACT 2005 standards for self-contained commercial refrigerators with transparent doors, which include self-contained service over counter units. For a full description of the analysis and results, please see section 5.3.3 of the preliminary analysis TSD chapter 5. This analysis showed that SOC.SC.M equipment was not capable, even at the max-tech level, of meeting the required standard level set by EPACT 2005 for self-contained refrigerators with transparent doors. For that reason, and because DOE did not have the authority to lessen the stringency of the legislatively prescribed EPACT 2005 standards, DOE excluded SOC.SC.M equipment from its analysis.

In December 2012, while the NOPR analysis for the current rulemaking was in progress, the American Energy Manufacturing Technical Corrections Act (AEMTCA), Pub. L. 112-210 (2012), amended EPCA to establish standards for self-contained service over counter refrigerators that belong to the equipment class SOC.SC.M. Paragraph (3) of section 4 of AEMTCA states as follows: "Each SOC-SC-M manufactured on or after January 1, 2012, shall have a total daily energy consumption (in kilowatt hours per day) of not more than 0.6 × TDA + 1.0." AEMTCA also directed DOE to determine, within three years of January 1, 2012, whether the standard established for equipment class SOC.SC.M should be amended, and if DOE determines that the standard should be amended, DOE should issue a final rule establishing an amended standard within 3 years of January 1, 2012.

The inclusion of this language in EPCA by way of AEMTCA allowed DOE to fully analyze the SOC.SC.M equipment class along with all other primary equipment classes in this rulemaking, and to propose a standard level to satisfy the requirement that DOE make a determination of amendment of standards within 3 years of January 1, 2012.

5.4 COST MODEL

One major output of the engineering analysis is the development of costs for the representative units analyzed at the baseline and at each higher design option level. These values were developed using a cost model that was divided into two parts for this rulemaking. The first of these was as standalone core case cost model, based on physical teardowns, that was used for developing the core case costs for the cabinets of each of the 25 directly analyzed classes. These core case costs consisted of the costs to manufacture the refrigerated case itself, consisting of structural members, insulation, shelving, wiring, etc., without the components that could directly affect energy consumption. The second part of the cost model was a component of the engineering analytical model, and operated in unison with the energy consumption model). This model received inputs in the form of the core case costs and the prices for design options implemented at and above the baseline, such as baseline and improved glass doors, higher-efficiency compressors, and higher-efficiency lighting. These two sets of data (core case 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 Development of Core Case Costs

The development of the case costs was based on physical teardowns of units available on the market at the time of the analysis. The first step in the assessment was the creation of a complete and structured bill of materials (BOM) from the disassembly of commercial refrigeration equipment from selected equipment classes. DOE dismantled each unit and characterized each part of the units according to weight, manufacturing processes, dimensions, material, and quantity. The result was a set of BOMs that included the costs for materials, components, and fasteners, and contained estimates for the cost of raw materials and purchased parts, and other costs such as labor, depreciation, and overhead costs. DOE based assumptions about the sourcing of parts and in-house fabrication on industry experience, information from trade publications, and discussions with manufacturers. DOE conducted interviews and plant visits with manufacturers to ensure accuracy in methodology and pricing.

The BOMs from the teardowns were fed into a factory model to produce estimates of MPCs for each of the units analyzed. Those estimates were then expanded to produce case costs for the equipment classes not directly examined via teardown. The cost model was based on production activities and divided factory costs into the categories shown in Table 5.4.1.

Table 5.4.1 Cost Model Output Classifications

Major Category	Sub-Category	Description
Material Costs	Direct	Raw materials (*e.g.,* coils of sheet metal) and purchased parts (*e.g.,* fasteners, wiring)
	Indirect	Supplies (*e.g.,* welding rods, die oil, release media)
Labor	Assembly	Parts / unit assembly on manufacturing line
	Fabrication	Conversion of raw material into parts ready for assembly
	Indirect	Fraction of overall labor not associated directly with equipment fabrication or assembly (*e.g.*, forklift drivers, quality control, purchasing of raw material and tools)
	Supervisory	Fraction of assembly, fabrication, and indirect labor 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
	Facility and Equipment Maintenance	Based on installed equipment and tooling investment
	Property Tax and Insurance	A fixed fraction based on total unit costs

The cost model analysis created cost estimates for each of the commercial refrigeration equipment units analyzed. The cost model used certain assumptions to provide cost estimates; the following sections describe those assumptions.

5.4.1.1 Selection of Units for Teardown Analysis

The selection of units for physical teardown analysis was performed in a manner so as to allow for the greatest coverage of the range of equipment modeled in this analysis and to provide sufficient data to allow for the expansion of the modeling to classes for which teardowns were not performed. This equipment covered all of the equipment families except for the HZO family, and spanned all three of the DOE rating temperatures. All of the equipment selected for teardown was self-contained equipment so that DOE could gain additional data for its modeling of other components (*e.g.,* coils and compressors) by analyzing the self-contained refrigeration systems. The equipment was chosen from the product lines of major manufacturers and at sizes similar to what DOE had determined to be an appropriate representative unit size for the given equipment class. All of the equipment selected for teardown analysis was at the current market baseline, without any customization or options intended to improve energy efficiency beyond the standard catalog offerings.

5.4.1.2 Manufacturer Production Cost Estimates and Assumptions

MPC includes the sum of direct labor, direct material, and overhead, including investment depreciation. The cost of specific models—or costs to individual manufacturers—will vary, depending on the equipment's precise characteristics, the actual manufacturing processes, the equipment mix in the factory, and other elements. There are also considerable differences in the levels of vertical integration (companies with a large market share and/or revenue base tend to be more vertically integrated than their smaller competitors) that affect cost structure and thus the cost of equipment. Yet, DOE assumed that all manufacturers buy at least some of their parts and/or subsystems from outside vendors.

The commercial refrigeration equipment market includes manufacturers that build a wide range of equipment—from mass-produced equipment to tailored, one-of-a-kind units. Most equipment listed in catalogs consists of general-purpose models that can then be customized to meet the particular needs of customers. Depending on the manufacturer and the degree of customization, engineering costs can thus represent a significant portion of the MPC for some producers of this equipment.

DOE built a parametric model that allowed the scaling of most input factors. The assumptions behind the model are based on published data by manufacturers, general industry practice (based on site visits), manufacturer interviews, and previously published DOE reports. DOE compared the model results to published unit data and list prices. For example, DOE compared listed shipping weights with the calculated weights for cabinets of representative units as a method of checking its results.

The lack of detailed teardowns for every equipment class and the varying degrees of vertical integration in the industry made calculating representative investment requirements difficult. Not only does the market share vary for each manufacturer across every equipment class, the scale of operations also varies greatly. It is also quite likely that high-volume manufacturers derive a cost advantage based on their purchasing volume for common raw materials and purchased parts alike. Lacking detailed data, DOE did not try to account for low- versus high-volume purchasing power in the development of the cost model, instead using industry-averaged aggregate data to represent all equipment offerings modeled.

5.4.1.3 Structure of the Cost Model

DOE used a detailed, component-focused manufacturing cost assessment methodology to estimate the MPC of each equipment class analyzed in the cost model, taking into account, for example, direct materials, direct labor, and factory overhead costs.

Following the development of detailed BOMs for each piece of equipment physically examined, DOE identified the major manufacturing processes and developed the spreadsheet model. Table 5.4.2 lists these examples of these processes.

Table 5.4.2 Examples of Major Manufacturing Processes

Fabrication	Finishing	Assembly/Joining
Fixturing	Washing	Adhesive bonding
Stamping/pressing	Powder coating	Spot welding
Brake forming	De-burring	Seam welding
Cutting and shearing	Polishing	Inspecting and testing
Insulating	–	–

DOE estimated fabrication process cycle times and entered them into the BOM. For this analysis, DOE estimated an average fully burdened hourly cost of labor based on the typical annual wages and benefits of industry employees. In the final step of the cost assessment, DOE estimated assembly times and associated direct labor costs.

Once the cost estimate for each unit was finalized, DOE prepared a detailed summary of relevant components, subassemblies, and processes. Because the intent of this cost modeling sub-analysis was solely to yield costs for the refrigerated case structures and not the design option components, assemblies accounted for by the design options (*e.g.,* glass doors, heat exchangers) were stripped away from the BOMs for each unit. The result was a set of costs corresponding to the MPCs for the core cases of each of the unit types analyzed.

The final step in the cost modeling process was to expand the results to apply to the remainder of the primary equipment classes for which teardowns were not performed. To achieve this, DOE added parametric scaling features to the model, which allowed the teardown units to be virtually scaled by size within the model. It also allowed material types, numbers of components, etc. to be modulated in order to best simulate the construction of representative units from other equipment classes. DOE incorporated features into these additional BOMs to reflect the necessary changes between equipment classes. For example, receiver valves were added to the models for remote condensing cases, and additional insulation thickness was taken into account for ice cream equipment. DOE utilized manufacturer data sheets and information gathered from interviews to aid in the modeling of these cases. The end result was a full set of 25 core case costs, which served as the starting point for the development of whole-system costs at the baseline and improved design option levels in the engineering model.

5.4.1.4 Material Prices

The cost model uses multiple proprietary databases to determine raw material costs and purchased part prices. Most prices are based on the most up-to-date data that the DOE has been able to obtain. The sole exceptions are metals prices, which are averaged over a 5-year period to reduce price volatility. Metals prices can have a large impact on the overall raw material costs and picking any particular point in time to select a raw material cost may hence lead to a distorted MPC.

As a general example, most refrigeration appliances contain significant amounts of copper in their heat exchangers, tubing, etc. Additionally, commercial refrigeration equipment is frequently externally clad in stainless steel for wash-down purposes. Figure 5.4.1 depicts copper and 304-series stainless steel price trends in the United States from 2002 to mid-2012. Note the extreme dip for both stainless steel and copper raw material costs in 2008. The price of copper more than halved from its previous high in 2007, a level that copper has since surpassed. In the example, the 5-year average price for copper is currently nearly a $1/lb lower than the current price while the two prices are about equivalent for 304-series stainless steel.

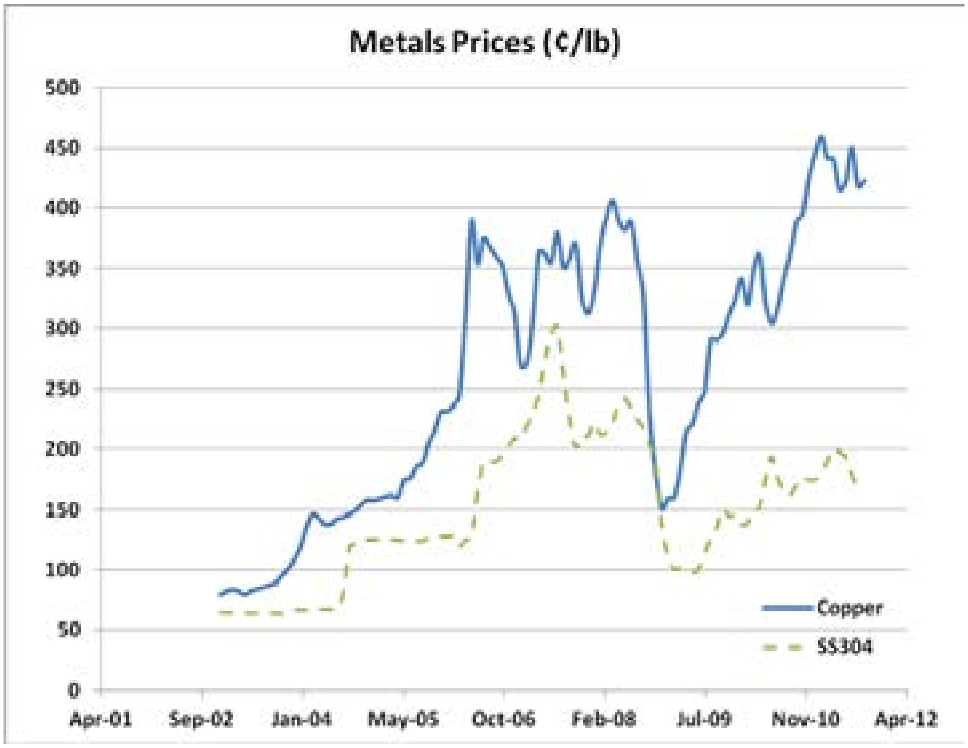

Figure 5.4.1 Copper and Stainless Steel Price Trends

By averaging metals raw materials costs over a 5-year period, the analysis is less affected by metals price volatility. The swings for other inputs (*e.g.,* plastics, purchased parts) are not as pronounced and hence current prices are used for them. Past quotes for materials and purchased parts are inflated using Bureau of Labor Statistics data and other sources, such as *American Metal Market*. Purchased part prices and raw material costs are reviewed with manufacturers at the appropriate purchasing volumes for accuracy.

5.4.1.5 Results

The result of the development of the core case cost model, generation of BOMs, parameterization, and extension of the cost model to classes for which physical teardowns were not performed was a set of 25 core case cost values. These values comprise the cost, for each representative unit, of manufacturing the housing, structural members, shelving, solid doors, wiring, and other components of the refrigerated case that do not vary by design option level. These core costs were entered into the engineering model and served as the starting points from which the costs of the units at various design option levels were developed.

5.4.2 Design Option Costs

Design option costs were developed independently of costs for the core case and 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, compressors, lighting, heat exchangers, night curtains, and other componentry considered as design options. For a listing of all components considered as design options, please see section 5.6.5. 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. For further details regarding the specific design options, please see section 5.6.5.

5.4.2.1 Light-Emitting Diode Price Forecasting

After release of the preliminary analysis documents for this rulemaking, DOE received comments from stakeholders stating that forecasts of the light-emitting diode (LED) lighting industry, including those performed by the Department, suggest that LED lighting is an emerging technology that will continue to experience significant price decreases in coming years. For this reason, 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"). In the appendix of this report, price projections from 2010 to 2030 were provided in $/klm for LED lamps and LED luminaires. 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 refrigerated case 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 commercial refrigeration equipment 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 as comprising the LED cost portions of the MPCs for the primary equipment classes.

5.4.3 Representative Unit Manufacturer Production Cost Values

For each representative unit analyzed in the engineering analysis, the analytical model calculated a cost at the baseline, as well as a cost at each design option level above the baseline up to the max-tech level. This was achieved by starting with the core case cost, developed as discussed in section 5.4.1, and adding to it the costs of the design options needed to represent all the components in a complete unit of the given equipment class. For example, a VCT self-contained refrigerator would require the core case cost plus the cost of its evaporator and condenser coils and fans, compressor, glass doors, and lighting to yield a baseline MPC. For units above the baseline, costs for improved design option levels were substituted by the analytical model in the order in which those design options were implemented.

5.5 MANUFACTURER SELLING PRICE

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, manufacturer markup, and the cost of shipping the units from the manufacturer to the first party in the distribution chain. The components of MSP are shown in greater detail in Figure 5.5.1.

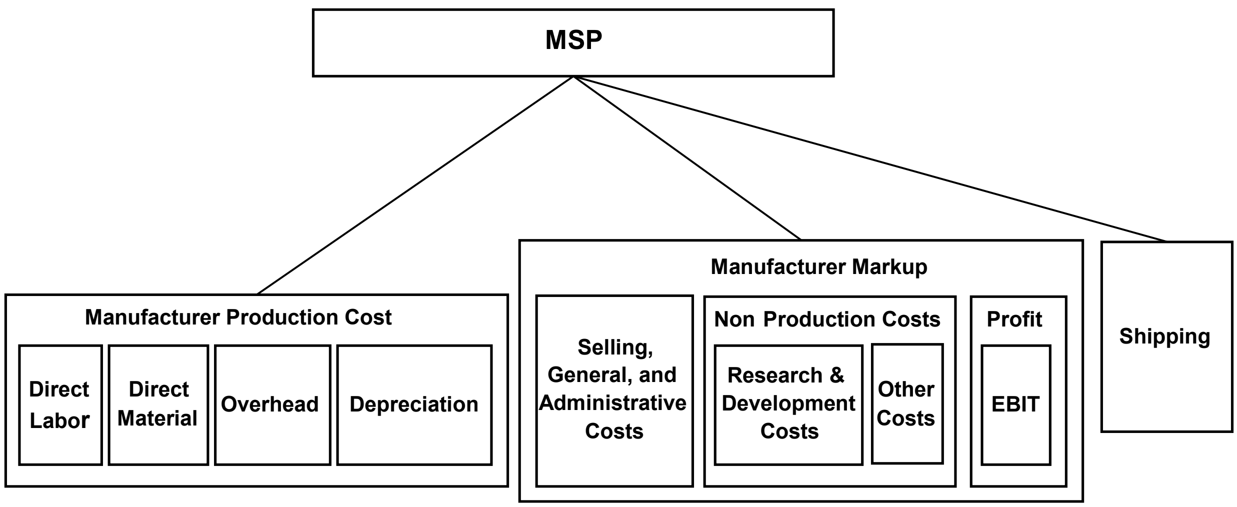

Figure 5.5.1 Components of Manufacturer Selling Price

The MSP is expressed as the product of the MPC and the manufacturer markup, added to the outbound shipping cost, as shown in Eq. 5.1:

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

Eq. 5.1

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

5.5.1 Manufacturer Markup

In its engineering analysis, DOE included manufacturer markup in the estimates of MSP. This markup consists of a value applied to the MPC estimates that accounts for non-production-cost elements of the MSP, including selling, general and administrative costs, research and development, interest, and profit. The manufacturer markup was calculated as a market share weighted average value applied to the entire industry. DOE developed this manufacturer markup by examining several major commercial refrigeration equipment manufacturers' gross margin information from annual reports and Securities and Exchange Commission (SEC) 10-K reports. Most of these companies are subsidiaries of more diversified parent companies that manufacture equipment other than commercial refrigeration equipment. Because the 10-K reports do not provide gross margin information at the subsidiary level, the estimated markups represent the average markups that the parent company applies over its entire range of equipment offerings and does not necessarily represent the manufacturer markup of the subsidiary. In its preliminary analysis, DOE estimated the average manufacturer markup to be 1.39. Based on further analysis and discussion with manufacturers during the NOPR stage of this rulemaking, DOE has adjusted this average manufacturer markup value to 1.42.

5.5.2 Representative Units

For each of the primary equipment classes analyzed in the engineering analysis, DOE developed a representative unit for which the cost and energy consumption would be modeled at each design option level.

DOE defined each representative unit quantitatively in the form of a set of design specifications at the baseline. These specifications included case dimensions, numbers of components, nominal power ratings, and other features that were necessary to calculate the energy consumption of a given unit. Table 5.5.1 shows the specifications that DOE defined for each representative unit. Not all specifications shown are applicable to every equipment class modeled (*e.g.*, specifications relating to doors would be inapplicable to open equipment).

Table 5.5.1 Representative Unit Specifications

Specification	Units
Case length	ft
Case gross refrigerated volume	ft^3
Case total display area	ft^2
Number of doors	#
Single door area	ft^2
Non-door glass area	ft^2
Non-door anti-sweat power	W
Wall area (ft^2)	ft^2
Insulation thickness	In.
Case interior surface area	ft^2
Air curtain angle from vertical	°
Infiltrated air mass flow	lb/hr
Number of bulbs in conditioned space	#
Number of bulbs not in conditioned space	#
Number of ballasts in conditioned space	#
Number of ballasts not in conditioned space	#
Evaporator fan nominal rated wattage	W
Number of evaporator fans per case	#
Condenser fan nominal rated wattage	W
Number of condenser fans per case	#
Discharge air temperature (DAT)	°F
Baseline evaporator temperature (SET)	°F
Baseline saturated condenser temperature (SCT)	°F
Compressor oversize multiplier	#
Defrost mechanism	n/a
Defrost time per day	hr
Defrost and drain heater power	W
Condensate pan heater power	W

In conjunction with the lowest technological level of each design option (section 5.6.5), these specifications were used in the engineering model to define the energy consumption and cost of baseline equipment on the market. The specifications that did not vary as a function of any design option (*e.g.,* case volume) were held constant from the baseline through to the max-tech configuration. Others (*e.g.,* discharge air temperature) were modified due to the implementation of higher technological levels of various design options. At these higher design option levels, the updated specifications were used to produce cost-efficiency data for more efficient equipment.

DOE established the baseline design specifications by reviewing available manufacturer data for equipment models offered across the range of available units within a given class. DOE focused this review on units exhibiting sizes and design characteristics that DOE had found through its market research to be most representative of the highest shipment volume offerings at the baseline for each equipment class analyzed. The aggregated data from this analysis were used to develop a representative unit for each equipment class with typical characteristics for physical parameters (*e.g.,* volume, TDA) and design features (*e.g.,* number of fans, number of light fixtures). Appendix 5A of this TSD provides these numerical specifications for each equipment class.

5.5.3 Shipping Costs

The third constituent component of the MSP, in addition to the MPC and the manufacturer markup, is the cost to ship the unit from the manufacturing facility to the first point on the distribution chain. Manufacturers stated that the specific party (manufacturer or buyer) that incurs that cost for a given shipment may vary based on the terms of the sale, the type of account, the manufacturer's own business practices, and other factors. However, for consistency, DOE includes shipping costs as a component of MSP. In calculating the shipping costs, DOE first gathered estimates of the costs to ship a full trailer of manufactured equipment an average distance in the United States. DOE then used the representative unit sizes to calculate a volume for each unit. Along with the dimensions of a shipping trailer and a loading factor to account for inefficiencies in packing, DOE used this cost and volume information to develop an average shipping cost for each equipment class directly analyzed.

5.6 ENERGY CONSUMPTION MODEL

The energy consumption model is the second key analytical model used in constructing cost-efficiency curves and is implemented in the engineering analysis spreadsheet. This model estimates the CDEC of commercial refrigeration equipment in kilowatt-hours (kWh) at various performance levels using a design option approach. The model is specific to the types of equipment covered under this rulemaking (described in chapter 3 of the TSD), but is sufficiently generalized to model the energy consumption of all covered equipment classes. DOE developed the energy consumption model, coupled with the system cost model, as a Microsoft Excel spreadsheet.

For a given equipment class, the model estimates the daily energy consumption for the baseline and the energy consumption of subsequent levels of performance above the baseline. The model calculates the energy consumption of each design option level separately.

5.6.1 Non-Numerical Assumptions

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

DOE based its analysis on the modeling of new equipment tested in a controlled-environment chamber subjected to the provisions of the DOE commercial refrigeration equipment test procedure. 77 FR 10292 (February 21, 2012). This test procedure incorporates Air-Conditioning, Heating, and Refrigeration Institute (AHRI) 1200-2010, which references the American National Standards Institute (ANSI)/American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 72-2005 (ASHRAE 72), *Method of Testing Commercial Refrigerators and Freezers*. Lighting occupancy sensors and scheduled controls, as well as night curtains, were modeled in the energy consumption model as specified in the DOE 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 ambient temperature, humidity, light level, and other requirements.

In performing the energy consumption calculations, DOE used normalized hourly refrigeration load values for calculating compressor power. When options such as lighting controls and occupancy sensors or night curtains were implemented over a portion of the 24-hour period, the energy savings during these periods were distributed across all 24 hours. Then, the average heat load per hour was used in combination with the calculated compressor energy efficiency ratio (EER) to determine daily compressor energy consumption. However, the model selected the appropriate compressor size based upon the maximum load (*i.e.*, the load without night curtains or occupancy sensors) to ensure sufficient heat-removal capacity. Normalization of heat loads was performed for the purposes of simplifying calculations and does not impact the final results.

DOE did not include a pull-down load associated with re-shelving products because the test procedure does not address product re-shelving. Product re-shelving is the act of loading new products into refrigerated display cases as existing products are sold. Typically, commercial refrigeration equipment is not designed to pull down the temperature of warm products, but only to display products that were already chilled or frozen in a refrigerated storage unit. An exception to this is in the case of beverage merchandisers, which are represented by the pull-down class included in this rulemaking analysis; however, this equipment is still tested at steady state, so pull-down load effects will not be quantified by testing.

While DOE did account for the heat load introduced into a case by defrost heaters, as well as the energy consumption of those heaters, DOE assumed that there are no pull-down loads associated with post-defrost periods. During 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, the merchandise in the case will typically have warmed several degrees. The merchandise must be returned to normal operating temperature when the refrigeration cycle resumes, adding an additional load to the condensing unit. Between equipment families and even within equipment classes there is a large variation in defrost mechanism, defrost cycle time, temperature recovery time, and product mass. Because of the uncertainty of these factors, DOE was unable to calculate the defrost pull-down load with sufficient certainty and did not include it in the model, but understands the impact of this phenomenon on daily energy consumption to be very small.

5.6.2 Numerical Constants and Assumptions

In developing the energy consumption model, DOE identified constants and made assumptions concerning numerical values used in the analysis. These include ambient conditions, financial assumptions, and parameters necessary to calculate the component and non-electric loads. Table 5.6.1 shows details of these assumptions.

Table 5.6.1 Energy Consumption Model Numerical Constants and Assumptions

Numerical Constants and Assumptions	Value	Source
Test chamber temperature *(°F)*	75	ASHRAE 72[1]
Test chamber relative humidity *(%)*	55	ASHRAE 72[1]
Test chamber pressure *(pounds per square in (psi), absolute)*	14.7	Assumed
Manufacturer markup *($/$)*	1.42	Publicly available corporate financial data
Fraction of anti-sweat heater power into case *(W/W)*	0.7	DOE estimate based on discussions with manufacturers
Fraction of lighting power into case for lighting outside of air curtain *(W/W)*	0.5	Electric Power Research Institute (EPRI), Supermarket Simulation Tool v3.0[2]
Lighting operating time per day *(hr)*	24	Assumed – for cases without occupancy sensors
Convective film coefficient inside case walls *(Btu/hr-ft^2-°F)*	4.00	Communication with the Southern California Edison Refrigeration & Thermal Test Center (RTTC)
Convective film coefficient outside case walls *(Btu/hr-ft^2-°F)*	1.46	Communication with RTTC
Overall U-factor of single-pane glass *(Btu/hr-ft^2-°F)*	1.059	Lawrence Berkeley National Laboratory WINDOW 5 Software[6]
Emissivity of test chamber walls *(-)*	0.9	Communication with RTTC
Emissivity of case inner walls *(-)*	0.9	Communication with RTTC
Area of test chamber walls *(ft^2)*	1,000	Communication with RTTC
Case interior relative humidity *(%)*	65	R. Faramarzi, Efficient Display Case Refrigeration, *ASHRAE Journal*, November 1999[3]
Evaporator coil overall bypass factor *(%)*	17	DOE estimate
High-efficiency compressor cost premium	5%	Communication with manufacturers
High-efficiency compressor power reduction	10%	Communication with manufacturers

5.6.3 Screened-In Technologies

The technology options that were analyzed (*i.e.*, were not screened out as part of the screening analysis, chapter 4) are as follows:

- higher efficiency lighting
- higher efficiency lighting ballasts
- remote lighting ballast location
- higher efficiency evaporator fan motors
- variable-speed evaporator fan motors and evaporator fan motor controllers
- improved evaporator coil design

- higher efficiency evaporator fan blades
- low-pressure differential evaporators
- case insulation increases or improvements
- improved transparent doors
- defrost mechanisms
- defrost cycle controls
- vacuum insulated panels
- occupancy sensors for lighting controls
- anti-fog films on transparent doors
- night curtains (equipment without doors only)
- higher efficiency compressors (self-contained equipment only)
- improved condenser coil design (self-contained equipment only)
- higher efficiency condenser fan motors (self-contained equipment only)
- higher efficiency condenser fan blades (self-contained equipment only)

5.6.4 Screened-In Technologies Not Considered in the Engineering Analysis

In the market and technology assessment (chapter 3 of the TSD), DOE defined an initial list of technologies that can reduce the energy consumption of commercial refrigeration equipment. In the screening analysis (chapter 4), DOE first shortened this list by eliminating from consideration those technologies that could potentially reduce field energy consumption of commercial refrigeration equipment but do not reduce energy consumption as measured by the DOE test procedure, because the test procedure conditions and requirements do not allow for these technologies to have a significant impact on the energy consumption values. These include location of remote lighting ballasts, variable speed evaporator motors and evaporator fan motor controllers, higher efficiency evaporator and condenser fan blades, insulation low-pressure differential evaporators, defrost cycle controls, and defrost mechanisms.

5.6.4.1 Remote Lighting Ballast Location

Relocation of fluorescent lamp ballasts outside the refrigerated space can reduce energy consumption by lessening the refrigeration load on the compressor. However, for the majority of commercial refrigeration equipment currently manufactured, ballasts are already located in electrical trays outside the refrigerated space, in either the base or top of the equipment. The notable exceptions are the equipment classes in the VCT equipment family, where ballasts are most often located on the interior of each door mullion.

Most commercial refrigeration equipment manufacturers purchase doors for VCT units that are preassembled with the entire lighting system in place rather than configured for separate ballasts. DOE believes that most commercial refrigeration equipment manufacturers choose these kinds of doors because it would be labor intensive and time consuming to relocate these ballasts at the factory and wire separate ballasts. This also aligns with the manufacturing practices of the door manufacturers, who often produce similar door designs, with integrated lighting, for many equipment types. Also, the potential energy savings are small because modern electronic ballasts are very efficient and do not significantly impact the refrigeration load. Therefore, DOE did not consider remote relocation of ballasts as a design option.

5.6.4.2 Variable-Speed Evaporator Fan Motors and Evaporator Fan Motor Controllers

Variable-speed evaporator fan motors, as well as evaporator fan motor controllers, allow fan motors to run at variable speed to match changing conditions inside the case. In practice, there is some opportunity for energy savings because the pressure drop of air moving across the evaporator coil varies significantly depending on the level of frost buildup on the coil. Theoretically, less fan power is required when the coil is free of frost, and variable-speed motors or controllers could adapt motor operation to these conditions. Moreover, such a system would also allow the coil to operate at a more stable temperature during frost buildup by varying fan speed proportionally.

However, there are also negative attributes to the implementation of such technologies. For example, the effectiveness of the air curtain in equipment without doors is very sensitive to changes in airflow, and fan motor controllers could disrupt the air curtain. The potential of disturbance to the air curtain, which could lead to higher infiltration loads, does not warrant the use of evaporator fan motor controllers in equipment without doors, even if there were some reduction in fan energy use. With respect to equipment with doors, DOE, in its discussions with manufacturers, found that there are concerns in industry about the implementation of variable-speed fan technology due to the need to meet food safety and maximum temperature requirements. Varying the fan speed would reduce the movement of air within the case, potentially leading to the development of "hot spots" in some areas of the case, where temperatures could exceed the desired value. Some industry representatives also stated that the use of such controllers could have unintended consequences, in which fans would be inadvertently run at full power to attempt to overcome a frosted or dirty coil, resulting in wasted energy. Due to the uncertainties that exist with these technologies, DOE did not consider variable-speed evaporator fan motors or evaporator fan motor controllers as a design option.

5.6.4.3 Higher Efficiency Evaporator and Condenser Fan Blades

Higher efficiency evaporator and condenser fan blades reduce motor shaft power requirements by moving air more efficiently. Current technology used in commercial refrigeration equipment is stamped sheet metal or plastic axial fan blades. These fan blades are lightweight and inexpensive. DOE was not able to identify any axial fan blade technology that is significantly more efficient than what is currently used, but did identify one alternative fan blade technology that might improve efficiency: tangential fan blades. They can produce a wide, even airflow, and have the potential to allow for increased saturated evaporator temperature (SET) through improved air distribution across the evaporator coil, which would reduce compressor power. However, tangential fan blades in small sizes are themselves less efficient at moving air, and thus require greater motor shaft power. Because of these competing effects, DOE did not consider tangential fan blades as a design option.

5.6.4.4 Low-Pressure Differential Evaporators

Low-pressure differential evaporators reduce energy consumption by reducing the power of evaporator fan motors, often by increasing the air gap between fins. However, in space-constrained equipment such as commercial refrigeration equipment, this reduction usually comes from a decrease in evaporator coil surface area, which generally requires a lower SET to achieve the same discharge air temperature and cooling potential. This, in turn, results in a reduction in compressor efficiency. Because of these competing effects, DOE did not consider low-pressure differential evaporators as a design option.

5.6.4.5 Defrost Cycle Control

Defrost cycle control can reduce energy consumption by reducing the frequency and duration of defrost periods. The majority of equipment currently manufactured already uses partial defrost cycle control in the form of cycle temperature-termination control. However, defrost cycle initiation is still scheduled at regular intervals. Full defrost cycle control would involve a method of detecting frost buildup and initiating defrost. As described in the market and technology assessment (chapter 3), this could be accomplished through an optical sensor or sensing the temperature differential across the evaporator coil. However, DOE understands that both of these methods are currently unreliable due to fouling of the coil with dust and other surface contaminants, which becomes more of an issue as cases age. Because of these issues, DOE did not consider defrost cycle control as a design option.

5.6.4.6 Defrost Mechanisms

Defrosting for medium-temperature equipment is typically accomplished with off-cycle defrost. Because off-cycle defrost uses no energy (and decreases compressor on-time), there is no defrost design option capable of reducing defrost energy in cases that use off-cycle defrost. Some medium-temperature cases and all low-temperature and ice-cream temperature cases use supplemental heat for defrost. Electric resistance heating (electric defrost) is commonly used in these cases. An alternative to electric defrost in those cases that require supplemental defrost heat is hot-gas defrost. This defrost mechanism involves using the hot compressor discharge gas to warm the evaporator from the refrigerant side. Manufacturers told DOE during interviews that the use of hot-gas defrost is a subject of division within the industry, with some manufacturers employing it on many of their models and others using it very rarely, if at all. These manufacturers mentioned various positive and negative attributes of the technology, depending on their stance on the issue. However, independent of the technical factors related to implementation of hot-gas defrost, the test procedure for commercial refrigeration equipment is not capable of quantifying the energy expenditure of the compressor during a hot-gas defrost cycle for remote condensing equipment. Therefore, DOE did not consider hot-gas defrost as a design option.

5.6.4.7 Anti-Fog Films on Transparent Doors

Anti-fog films are offered as an option by some manufacturers on their transparent display doors and consist of advanced hydrophobic materials that are applied to the glass surface on the inside of the door. Without such coatings, condensation can attach to the glass surface and form beads, resulting in visible fog that can obscure views of the product. These materials cause the water to instead simply slide off the surface of the door, maintaining a clear appearance. However, DOE understands that these films alone do not necessarily eliminate the need for anti-sweat heaters in many cases, including conditions of high ambient humidity, as these films do not eliminate the issue of potential condensation on the outside of the case, which can present a major problem for consumers. Moreover, DOE understands that delamination of anti-fog films presents a major issue, making them unreliable in the long term. Discussions with manufacturers have led DOE to believe that other improvements in door construction provide the capacity to reduce anti-sweat heat without the drawbacks previously discussed. Because of these issues, DOE did not consider anti-fog films on transparent doors as a design option.

5.6.5 Design Options

After conducting the screening analysis and removing from consideration those technologies described above, DOE implemented the remaining technologies as design options in the energy consumption model:

- higher efficiency lighting and occupancy sensors for VOP, SVO, and SOC equipment families (horizontal fixtures)
- higher efficiency lighting and occupancy sensors for VCT and PD equipment families (vertical fixtures)
- improved evaporator coil design
- higher efficiency evaporator fan motors
- improved case insulation
- improved doors for VCT equipment family, low and ice-cream temperature
- improved doors for VCT and PD equipment families, medium temperature
- improved doors for HCT equipment family, low and ice-cream temperature
- improved doors for HCT equipment family, medium temperature
- improved doors for SOC equipment family, medium temperature
- improved condenser coil design (for self-contained equipment only)
- higher efficiency condenser fan motors (for self-contained equipment only)
- higher efficiency compressors (for self-contained equipment only)
- night curtains (equipment without doors only)

Each design option has at least two technology levels, ranging from the minimum (lowest performing) to the maximum (best performing) technology. The design options and the technology levels for each design option are described in the following sections.

5.6.5.1 Higher Efficiency Lighting and Occupancy Sensors

Lighting is an important characteristic of commercial refrigeration equipment because it makes the product visible to the consumer. Lighting systems typically operate continuously and provide an opportunity for significant energy savings. As lighting system efficiency increases, reductions in total case energy consumption can be achieved through a direct reduction in electricity consumption by the lighting system, and a reduction of heat inside the case, thereby reducing compressor work.

It is important that product illumination not degrade with higher design option levels because this would decrease the utility of the equipment. DOE tried to maintain approximately constant system illumination across all design option levels. This approach meant that DOE had to consider lighting as a system, rather than distinguishing lamps and ballasts as separate design options. This approach becomes more important when considering LED lighting systems, which do not use ballasts, as fluorescent lighting systems do.

Although LED systems generally have lower absolute efficacy in lumens per watt than fluorescent systems, the fixtures produce light that is much more directional in nature. And, while the total lumen output of LED systems is lower than comparable fluorescent systems, the amount of light incident on the product (illuminance) is roughly equivalent. Consultations with commercial refrigeration equipment manufacturers, lighting manufacturers, and other technical experts indicate that current LED technology provides product lighting that is adequate and in most cases comparable to fluorescent lighting. In recent years, according to discussions with manufacturers, the trend within the market has been toward a much greater use of LED lighting in this equipment.

To account for the variation in design between equipment families, DOE used two lighting design options in the energy consumption model. DOE used the "higher efficiency lighting and ballasts for VOP, SVO, and SOC equipment families" design option for lighting in a horizontal configuration, and the "higher efficiency lighting and ballasts for VCT and PD equipment families" design option for the lighting in a vertical configuration. The VCS and HCS equipment families do not require lighting because they are not designed to display food, while the HCT and HZO equipment families typically do not have lighting because they rely on store ambient lighting for product illumination. Therefore, DOE did not consider lighting design options for these four equipment families.

DOE also considered occupancy sensors, which allow for case lighting to be reduced or shut off during periods of inactivity around the case, as part of the design options for the VCT/PD and VOP/SVO/SOC groupings. These equipment families generally are used for display purposes and include lighting for product illumination, making occupancy sensor implementation an option for this equipment. Because fluorescent lamps require a start-up period after being powered on and fluorescent lamp lifetime is greatly reduced by frequent cycling on and off, DOE only considered occupancy sensors to be an option compatible with LED lighting.

In the preliminary engineering analysis, DOE based its modeling of occupancy sensors on past empirical studies and discussions with commercial refrigeration equipment manufacturers. For that analysis, DOE determined that a net 30-percent reduction in lighting run time due to the implementation of occupancy sensors would be an appropriate figure for modeling the performance of these sensors.[4, 5] This value was directly implemented into the energy consumption model, such that a unit with occupancy sensors would see a lighting time reduction of 30 percent from the standard 24-hour daily run time. However, in the time since those analyses were performed, DOE published a final rule amending the commercial refrigeration equipment test procedure. 77 FR 10292 (February 21, 2012). That rule includes provisions for the testing of occupancy sensors and scheduled controls, allowing for 8 to 10.8 hours of lighting off or dimmed, depending on whether lighting occupancy sensors, scheduled lighting controls, or both are installed on a case and whether the respective lighting technologies dim or turn off the lights. For this analysis, DOE assumed 2.8 hours of dimmed lighting from sensors and an 8-hour lighting run time reduction due to scheduled controls per 24-hour test period. DOE believes this is lighting configuration is representative of those found in the field, and DOE incorporated these specifications from the updated DOE test procedure into the standards NOPR engineering analysis. The reduction in lighting run time, as input into the model, affects both the calculated energy consumption of the lighting and the lighting contribution to the case heat load. Additionally, in some cases, where incremental implementation of occupancy sensors proved in the analysis to be more cost effective than the implementation of LEDs alone, DOE implemented the two together, going directly from T8 or Super T8 lighting to LEDs with occupancy sensors, without an intermediate option of LEDs alone.

Because of the horizontal configuration of shelving and the linear nature of display case lineups in the VOP, SVO, and SOC equipment families, lighting for these cases is typically installed in the horizontal plane. Details for the "higher efficiency lighting and ballasts for VOP, SVO, and SOC equipment families" design option are shown in Table 5.6.2. Remote condensing versions of these display cases are most often sold in 8-foot and 12-foot sections, using multiples of 4-foot fixtures (either fluorescent bulbs or LED strips) to continuously light the entire width of the case. Self-contained versions are commonly sold in 4-foot lengths, so that a single 4-foot light fixture will light the full width of the case. Therefore, 4-foot fixtures were specified for all lighting systems in the horizontal configuration. This lighting was also required to have a color temperature of 3,500 kelvin (K), which is typical for this type of equipment.

Table 5.6.2 Details for Lighting for VOP, SVO, HZO, and SOC Equipment Families Design Option

Level	Description	Lamp Type	Lamp Rated Power *W*	Lamp Rated Light Output *lumens*	System Efficacy *lumens/W*	System Light Output *lumens*
T8N	4 ft, T8 Elec.	F32T8	32.0	2,850.0	85.0	2,679.0
T8S	4 ft, Super T8 Elec.	F32T8/HL	32.0	3,100.0	94.6	2,697.0
LED	4 ft, LED	LED 4 ft	15.0	888.0	59.2	888.0
OCC	4 ft, LED with Occupancy Sensors	LED 4 ft	15.0	888.0	59.2	888.0

Because of the vertical configuration of the doors in the VCT and PD equipment families, fluorescent lamps typically are installed vertically behind the mullions between doors. Such lighting systems typically consist of a single 5-foot lamp and single ballast per mullion as well as a lamp installed at each end of the case. All lighting systems in the vertical configuration were specified to have 5-foot lamps and a color temperature of 4,100 K, which DOE found to be typical for this equipment family. Table 5.6.3 shows details for the "lighting for VCT and PD equipment families" design option.

Table 5.6.3 Details for Lighting for VCT and PD Equipment Families Design Option

Level	Description	Lamp Type	Lamp Rated Power *W*	Lamp Rated Light Output *lumens*	System Efficacy *lumens/W*	System Light Output *lumens*
T8N	5 ft, T8 Elec.	F58T8/835	58.0	5,400.0	93.1	5,400.0
LED	5 ft, LED	LED 5 ft	29.0	1,564.0	53.9	1,564.0
OCC	5 ft, LED with Occupancy Sensors	LED 5 ft	29.0	1,564.0	53.9	1,564.0

5.6.5.2 Higher Efficiency Evaporator Fan Motors

In conjunction with fan blades, fan motors are necessary for transferring heat from the display case to the refrigerant and, in the case of self-contained equipment, rejecting heat from the refrigerant into the ambient air. Fan motors are also responsible for maintaining product temperatures and air curtains on open cases. They must operate virtually continuously, and therefore use a significant amount of energy. As motor efficiency increases, reductions in total case energy consumption are achieved through a direct reduction both in electricity consumption and waste heat inside the case, reducing compressor load.

Table 5.6.4 shows details for the evaporator fan motor design option. DOE considers shaded-pole motors (SPM) as the baseline (or lowest-efficiency) technology, permanent split capacitor (PSC) motors as the mid-level technology, and brushless direct current or electronically commutated motors (ECMs) as the maximum technology level. DOE adapted motor efficiency levels, listed in Table 5.6.4, from the 2009 final rule and ongoing DOE rulemaking efforts. DOE verified these efficiency estimates through discussions with equipment manufacturers. During its discussions with manufacturers, some manufacturer representatives pointed out that there can be significant variations in efficiency between motors of the same type but different models. According to these manufacturers, this variation was largely a function of equipment supplier. Some manufacturers stated that, from higher quality suppliers, some specific models of PSC motors, for example, could reach efficiencies as high as 40 percent. However, manufacturers generally agreed that the values listed in Table 5.6.4 are fairly representative of the efficiencies of motors available for use in commercial refrigeration equipment. Therefore, DOE retained these values for use in its NOPR engineering analysis.

Table 5.6.4 Details for Evaporator Fan Motor Design Option

Rated Power *W*	Shaded-Pole Motor		Permanent Split Capacitor Motor		Brushless DC Motor (ECM)	
	Actual Power *W*	Efficiency *%*	Actual Power *W*	Efficiency *%*	Actual Power *W*	Efficiency *%*
12.0	60.0	20	41.4	29	18.2	66
9.0	45.0	20	31.0	29	13.6	66
6.0	30.0	20	20.7	29	9.1	66

5.6.5.3 Improved Evaporator Coil Design

Evaporator coils are another component necessary for transferring heat from the display case to the refrigerant. Table 5.6.5 shows details for the evaporator coil design options used in the NOPR engineering analysis. In view of available information, DOE considered a baseline and a maximum technology level for this design option. For each level, DOE specified an overall UA-value[a] and a coil cost. The UA-value is normalized to the standard coil value, and the coil cost is normalized to the heat removal capacity of the coil. This allowed DOE to apply these details of coil design across all equipment classes and at different capacities. In consultation with

[a] The overall UA-value is the product of the overall heat transfer coefficient (Btu/h-ft^2-°F) and the total surface area (ft^2) of the coil. This value can be derived from the total heat transfer rate of the coil (Btu/h) divided by the average temperature difference between the discharge air and the saturated evaporator temperature (ΔT).

outside experts, DOE determined that applying the same coil design improvements to different sized coils would result in similar increases in coil performance.

Table 5.6.5 Details for Evaporator Coil Design Option

Level	Description	Normalized UA (-)
EVAP1	Standard Coil	1
EVAP2	High-Performance Coil	1.745

DOE based the details of coil construction (Table 5.6.6) on baseline and prototype high-performance coil specifications developed by DOE contractors. These coil designs were developed by first performing teardown analyses of existing coils on the market and then using the data as inputs into a numerical simulation model to develop performance values for those baseline designs. The same modeling tools were then used to calculate new performance estimates for improved coil designs based on manipulation of the physical coil parameters. Finally, the baseline and improved coil designs were input into the cost model in the same manner as the core cases discussed in section 5.4.1 to yield costs to manufacture each design. The high-performance coil uses a combination of enhancements to the heat transfer surfaces to increase its overall UA-value. These enhancements include higher fin thickness, rifled tubing, and the addition of an extra row of tubes to the coil. In sum, these improvements allow the prototype coil to run at a SET that is warmer than the baseline coil while maintaining the same discharge air temperature and heat removal capacity.

Table 5.6.6 Properties of Standard and Enhanced Evaporator Coil Designs

Property	Standard Coil	High-Performance Coil
Overall width (*in.*)	40.5	40.5
Overall height (*in.*)	8.0	10.0
Overall depth (*in.*)	6.25	7.50
Tube rows transverse to airflow	4	5
Tube rows parallel to airflow	5	6
Tubing material	Copper	Copper
Tubing outer diameter (*in.*)	.375	.375
Tubing wall thickness (*in.)*	.012	.012
Tubing inner surface	Smooth	Rifled
Fin material	Aluminum	Aluminum
Fin surface	Flat	Flat
Fin pitch (*fins per inch*)	3	3

Because compressor performance is directly related to SET, reductions in total case energy consumption are realized through an improved EER at the condensing unit. In consultation with outside experts, DOE determined that applying the same coil improvements to different sized coils and at different temperatures would result in similar SET improvements. Consequently, the coil design was scaled as appropriate to model the coil in the representative unit for each equipment class analyzed.

5.6.5.4 Improved Insulation and Vacuum Insulated Panels

Several technology levels representing improvements to case insulation were implemented in the engineering model. DOE included increased foam insulation thickness as a design option, and modeled a half-inch increase in insulation thickness for all equipment classes based on discussions with manufacturers regarding case design and foam insulation fixturing. DOE added this increase in thickness to the baseline value of insulation thickness and recalculated the conduction load in the energy consumption model (section 5.6.6.5). The cost of increasing the insulation thickness includes a sunk cost per unit, considering foam fixture engineering and tooling costs, production line lifetime, and number of fixtures and units produced. In the 2009 final rule and in its preliminary engineering analysis for this rulemaking, DOE assumed the cost increase due to additional foam material to be insignificant compared to the cost of upgrading foam fixtures. However, in response to stakeholder comments after the preliminary analysis, DOE included the differential cost of additional foam insulation in the engineering analysis for the NOPR. DOE calculated the volume of additional insulation resulting from the added half inch of thickness and multiplied this by a cost per cubic foot for the foam and blowing agent. Table 5.6.7 provides details of the assumptions used to calculate the additional cost of insulation thickness increases.

Table 5.6.7 Assumptions in Cost Calculation Methodology for Insulation Thickness Increase

Item	Value	Notes
Cost to upgrade single insulation fixture	$100,000	
Number of fixtures	25	Based on a survey of the number of products offered by each manufacturer
Engineering costs	$416,667	Assumes $100,000 per year cost of labor and one month to complete redesign per machine plus one month for testing
Interest rate	7.0%	
Product line lifetime *(years)*	7.0	
Units per year	25,000	
Sunk fixturing cost per unit	$21.65	

DOE also considered vacuum insulated panels (VIPs) as an option for improving the insulation performance of the insulated walls of commercial refrigeration equipment cases. Data regarding VIP performance was gathered from discussions with VIP manufacturers in conjunction with past and ongoing rulemakings on residential refrigerators and walk-in coolers and freezers. These discussions yielded a representative material cost for VIPs with an R-value of 30 per inch of thickness. This cost was then multiplied in the engineering cost model by the insulated wall area and thickness to produce a differential cost of upgrading from traditional foam insulation to VIPs. This model simulated the entire modeled case as being composed of VIP material, and assumed that the VIP material would be the dominant component of the thermal performance of the case. Additionally, as with the increased foam thickness design option, a sunk cost per unit of upgrading to VIPs was calculated and applied to the unit cost. This consisted of an estimate for the additional costs of product engineering and redesign, new production equipment, and new tooling, amortized over the typical equipment production lifetime and divided by the number of units per year. The result was a levelized cost per commercial refrigeration equipment case produced. The assumptions used for this design option are shown in Table 5.6.8.

Table 5.6.8 Assumptions in Cost Calculation Methodology for Vacuum Insulated Panels

Item	Value
Additional tooling/engineering/product redesign costs	$500,000
New equipment costs	$300,000
Interest rate	7.0%
Product line lifetime *(years)*	7
Units per year	25,000
Sunk cost per unit	$5.94

For each equipment class analyzed, DOE considered both the increase in conventional insulation thickness and the switch to VIPs as design options. While these insulation improvement design options benefit some equipment types more than others, DOE modeled them for each of the directly analyzed equipment classes, as conduction through the case is present in all equipment classes. Table 5.6.9 summarizes these design options.

Table 5.6.9 Details for Insulation Design Options

Level	Description	Additional Thickness Above Baseline *inches*	Insulation R-Value Per Inch Thickness
IN1	Baseline insulation	0	8
IN2	Extra 1/2-inch insulation thickness	0.5	8
VIP	Vacuum insulated panels	0	30

5.6.5.5 Improved Transparent Doors

Transparent doors allow refrigerated products to be displayed to consumers while keeping cold air inside the display case. Transparent doors also allow heat to radiate into the display case and generally have a lower insulation value than solid insulated walls. In cases with transparent doors, these surfaces are responsible for a significant portion of the case heat load. On freezers and some refrigerators, glass doors must be heated to prevent frost or condensation from forming. These “anti-sweat” heaters, which are used to prevent formation of frost or condensation on the glass doors, often run continuously and consume significant amounts of energy. Reductions in total case energy consumption can be achieved both by improving the overall insulation value (U-factor) of the door and by reducing the required anti-sweat heater power. Improvements to heat transfer performance could include the use of additional panes of glass and expanded use of inert gas fill between panes of glass. The treatment of the window glass with advanced low-emissivity coatings and increasing the number of coated surfaces could also reduce losses resulting from radiation heat transfer. Reductions in the anti-sweat heater power needed can often be achieved as a function of improved conductive performance of the door, as well as in improvements to the gasketing and other door features.

A wide variety of door types are used on the equipment covered in this rulemaking. Door construction and performance can vary by equipment family as well as operating temperature of the case. To account for this variation, DOE developed separate design option data for each of the different door types represented in the primary equipment classes that DOE analyzed. For selected door designs, DOE estimated the thermal performance of the door (expressed as an overall U-factor) using information about door construction obtained from manufacturers and the

WINDOW 5 modeling software, available from Lawrence Berkley National Laboratory.[6] This performance data was cross-referenced from DOE's ongoing rulemaking on walk-in coolers and freezers, as the major door manufacturers for the commercial refrigeration equipment industry also possess a large share of the market for walk-in display doors and identical door designs are often shared across these applications. Cost estimates for transparent doors for commercial refrigeration equipment applications were obtained from manufacturer interviews and publicly available sales sheet data. DOE then extended this cost and performance data to apply to various geometries of horizontal and vertical display and service doors.

Doors for the VCT equipment family operating at low and ice-cream temperature are hinged and are a representative size of 30 inches wide and 67 inches tall with three panes of glass. Table 5.6.10 shows details of thermal performance and anti-sweat heater requirements for this door type.

DOE considered two technology levels for this design option: the high-performance door that uses a combination of low-emissivity coating, frame material, and inert fill-gas to reduce the overall U-factor; and a standard door.

Table 5.6.10 Details for Doors for VCT Equipment Family, Low and Ice-Cream Temperature Design Option

Level	Description	Overall U-Factor *Btu/hr-ft²-°F*	Anti-Sweat Heater Power *W/door*
DR1	Standard door	0.19	165
DR2	High-performance door	0.10	80

Doors for the VCT and PD equipment families operating at medium temperature are hinged and have a representative size of 30 inches wide and 67 inches tall with two panes of glass at the baseline. Table 5.6.11 shows details of thermal performance and anti-sweat heater requirements for this door type.

DOE considered two technology levels for this design option. The high-performance door uses a combination of an additional pane of glass, low-emissivity coating, frame material, and inert fill-gas to reduce the overall U-factor compared to the standard door. Based on interviews conducted with commercial refrigeration equipment manufacturers, DOE understands that the implementation of these sorts of high-performance glass doors in medium-temperature equipment can allow for the complete elimination of anti-sweat power. As a result, the high-performance door design option for the VCT and PD families at medium temperature includes an anti-sweat heater power of zero.

Table 5.6.11 Details for Doors for VCT and PD Equipment Families, Medium Temperature Design Option

Level	Description	Overall U-Factor *Btu/hr-ft²-°F*	Anti-Sweat Heater Power *W/door*
DR1	Standard door	0.26	50
DR2	High-performance door	0.16	0

Doors for the HCT equipment family operating at medium temperature are sliding and are a representative size of 18 inches wide and 20.5 inches tall with one pane of glass at the baseline. Table 5.6.12 shows details of thermal performance and anti-sweat heater requirements for this door type.

DOE considered two technology levels for this design option. The high-performance door uses a combination of an additional pane of glass, low-emissivity coating, frame material, and inert fill-gas to reduce the overall U-factor compared to the standard door. Typically, these door types do not require anti-sweat power.

Table 5.6.12 Details for HCT Equipment Family, Medium Temperature Design Option

Level	Description	Overall U-Factor *Btu/hr-ft²-°F*	Anti-Sweat Heater Power *W/door*
DR1	Standard door	1.05	0
DR2	High-performance door	0.26	0

Doors for the HCT equipment family operating at low and ice-cream temperatures are sliding and are a representative size of 18 inches wide and 20.5 inches tall with one pane of glass at the baseline. Table 5.6.13 shows details of thermal performance and anti-sweat heater requirements for this door type.

DOE considered two technology levels for this design option: a high-performance door that uses a combination of low-emissivity coating, frame material, and two extra panes of glass with inert fill-gas to reduce the overall U-factor; and a standard door. Typically, these door types do not require anti-sweat heater power. Due to equipment design constraints, the doors considered for HCT equipment operating at low and ice-cream temperatures were identical to those considered for the medium-temperature equipment.

Table 5.6.13 Details for Doors for HCT Equipment Family, Low, and Ice-Cream Temperature Design Option

Level	Description	Overall U-Factor *Btu/hr-ft²-°F*	Anti-Sweat Heater Power *W/door*
DR1	Standard door	1.05	0
DR2	High-performance door	0.26	0

Doors for the SOC equipment family operating at medium temperature are of the sliding type and have a representative size of 24 inches wide and 20 inches tall with two panes of glass. Table 5.6.14 shows details of door thermal performance and anti-sweat heater requirements for this door type. DOE considered two technology levels for this design option: a high-performance door that uses a combination of low-emissivity coating, frame material, and inert fill-gas to achieve a reduced overall U-factor; and a standard door. Typically, SOC doors do not require anti-sweat heater power.

Table 5.6.14 Details for Doors for SOC Equipment Family, Medium Temperature Design Option

Level	Description	Overall U-Factor *Btu/hr-ft²-°F*	Anti-Sweat Heater Power *W/door*
DR1	Standard door	0.26	0
DR2	High-performance door	0.16	0

5.6.5.6 Higher Efficiency Condenser Fan Motors

The condenser fan motor design option applies only to those equipment classes that are self-contained. Details for the condenser fan motor design option are identical to those shown in Table 5.6.4. As with evaporator fan motors, the SPM is the baseline technology, the PSC motor is the mid-level technology, and the ECM is the maximum technology level. Because condenser fan motors are outside the refrigerated space, efficiency improvements only affect the direct electrical consumption of the motors and not the total case heat load.

5.6.5.7 Improved Condenser Coil Design

For the NOPR stage of this rulemaking, DOE performed additional analysis of condenser coils to develop a more thorough set of inputs to the energy consumption model for self-contained equipment. Table 5.6.15 shows details for this design option. Details of coil construction are based on data from teardowns of equipment available on the market, as well as analytical modeling performed by DOE and its contractors. The methods used for developing the condenser coil model were the same as those used to model evaporator coils and are described in section 5.6.5.3. Based on this information, DOE considered both baseline and high-performance technology levels for this design option. For each level, DOE specified an overall UA-value and a coil cost. The UA-value is normalized to the standard coil, and the coil cost is normalized to the heat removal capacity of the modeled coil in British thermal units per hour. This approach allowed DOE to apply the details of coil design across all self-contained equipment classes. In consultation with outside experts, DOE determined that applying the same coil improvements to different sized coils would result in similar performance improvements.

Table 5.6.15 Details for "Increased Condenser Surface Area" Design Option

Level	Description	Normalized UA (-)
COND1	Standard coil	1.00
COND2	High-performance coil	2.315

Table 5.6.16 shows details of coil construction. The high-performance coil uses a combination of enhancements to the heat transfer surfaces that increased its overall UA-value. These enhancements include rifled tubing, increased fin pitch and thickness, and an added row of tubes. These improvements allow the prototype coil to run at a saturated condenser temperature (SCT) that is cooler than the baseline coil while maintaining the same heat rejection rate. Because compressor performance is directly related to SCT, reductions in total case energy consumption are achieved through an improved EER at the condensing unit.

Table 5.6.16 Properties of Standard and Enhanced Condenser Coil

Property	Standard Coil	High-Performance Coil
Overall width (*in.*)	27	27
Overall height (*in.)*	12.0	14.4
Overall depth (*in*.)	3.375	4.5
Tube rows transverse to airflow	10	12
Tube rows parallel to airflow	3	4
Tubing material	Copper	Copper
Tubing outer diameter (*in*.)	.3825	.3825
Tubing wall thickness (*in.)*	.02	.02
Tubing inner surface	Smooth	Rifled
Fin material	Aluminum	Aluminum
Fin surface	Flat	Flat
Fin pitch (fins per inch)	6	7

5.6.5.8 Higher Efficiency Compressors

In consultation with manufacturers and external technical experts, DOE determined that two levels of technology were applicable for the compressor design option. The baseline technology level is a standard single-speed hermetic compressor, and the maximum technology level is a high-efficiency single-speed hermetic compressor. Reductions in total case energy consumption are achieved through a reduction in compressor power consumption.

Several manufacturers provide performance data for standard single-speed hermetic compressors over a range of capacities applicable to the covered equipment. DOE used this data to find appropriately sized compressors when developing each design option curve. (See section 5.6.6.2 for information on the calculation of compressor energy consumption.) During the NOPR analyses, DOE updated its selection of compressor models within the engineering analytical spreadsheet to better account for the wide variations in capacity between the representative unit sizes analyzed for the various equipment classes.

Although several compressor manufacturers produce high-efficiency compressors, little data are currently available on their performance. Often, compressor manufacturers do not explicitly brand their compressors as “high-efficiency,” but instead maintain only one line of products for a given application. Therefore, DOE approximated a set of high-efficiency compressors by adjusting the power consumption of the standard compressors using a constant multiplier. This multiplier assumed a 10-percent reduction in energy consumption with an associated 5-percent cost premium. DOE developed this multiplier through its own research, consultation with outside experts, and verification through discussion with commercial refrigeration equipment manufacturers.

Some manufacturers mentioned in interviews that scroll compressors were available from certain producers for commercial refrigeration equipment applications. However, these manufacturers also stated that the scroll compressors, while presenting a slight performance improvement over reciprocating compressors, had an extremely high associated cost premium. These manufacturers stated that this cost premium made scroll compressors a viable option only in specific design scenarios, such as when certain geometric configurations were required or in instances where noise reduction is very important. They also mentioned that scroll compressors were only available over a certain range of capacities, which would not cover the entire commercial refrigeration equipment market. As a result, DOE did not consider scroll compressors in its analysis.

At the preliminary analysis public meeting and in written comments submitted during the preliminary analysis comment period, several stakeholders raised the subject of variable-speed compressors as applicable to commercial refrigeration equipment. DOE researched this subject and raised it during interviews with commercial refrigeration equipment manufacturers. According to these sources, only one compressor manufacturer currently sells a variable-speed compressor for commercial refrigeration applications in the United States, and that product is sized only for equipment with heat loads less than 3,000 Btu per hour. Such a compressor size would be applicable only to some smaller open cases and medium-sized equipment in classes with doors. Additionally, manufacturers raised concerns regarding the state of the technology at this time, saying that not enough research and development had been performed to evaluate the efficacy and reliability of variable-speed compressors for commercial refrigeration application. These compressors would also require complex controls and sensor-driven interfaces to be developed. As a result, DOE has elected not to consider variable-speed compressors explicitly in its analysis because its current understanding is that this technology has not yet been implemented for widespread use within the commercial refrigeration equipment industry.

5.6.5.9 Night Curtains

In response to stakeholder input and discussions with commercial refrigeration equipment manufacturers, DOE included night curtains as a design option for the VOP and SVO equipment families in the engineering analysis. DOE based its modeling of this design option on specifications obtained from manufacturer interviews, publicly available data from night curtain manufacturers, and past studies of night curtain performance. For cases with night curtains implemented, a curtain down time of 6 hours per day was used in the energy consumption model, in accordance with the time specified in the commercial refrigeration equipment test procedure final rule. 77 FR 10292 (February 21, 2012). The performance of the curtains in the model was based on a survey of field studies of night curtain effectiveness, which resulted in an average 39-percent reduction in case heat load during periods when the night curtains were deployed.[7,8] When the night curtain design option was implemented in the energy consumption model, the 39-percent reduction in case heat load was applied over a period of 6 hours to the load calculated for the same configuration unit without night curtains, and the new heat load was normalized over 24 hours to give a standard hourly load. Table 5.6.17 shows the specifications for the night curtain design option.

Table 5.6.17 Details for "Night Curtains" Design Option

Level	Description	Curtain Down Time *hr*	Case Heat Load Multiplier
OFF	No night curtains	0	1.00
NC1	Night curtains	6	0.61

5.6.6 Model Components

Figure 5.6.1 presents a schematic showing the components in the energy consumption model. The model calculates energy consumption in two major subsections (expressed as kWh/day): compressor energy consumption and component energy consumption. Component energy consumption is the sum of electrical energy directly consumed by each fan motor, lamp, defrost and drain heater, anti-sweat heater, and pan heater.

Compressor energy consumption is calculated from the total heat load (expressed as Btu/hr) and one of two compressor models: one version for remote condensing equipment, and one for self-contained equipment. The total heat load is a sum of the component load and the non-electric load. The component load is a sum of the heat emitted by evaporator fan motors, lighting, defrost heaters, drain heaters, and anti-sweat heaters inside and adjacent to the refrigerated space (condenser fan motors and pan heaters are outside the refrigerated space and do not contribute to the component heat load). The non-electric load is the sum of the heat contributed by radiation through glass and openings, heat conducted through walls and doors, and warm air infiltration through openings.

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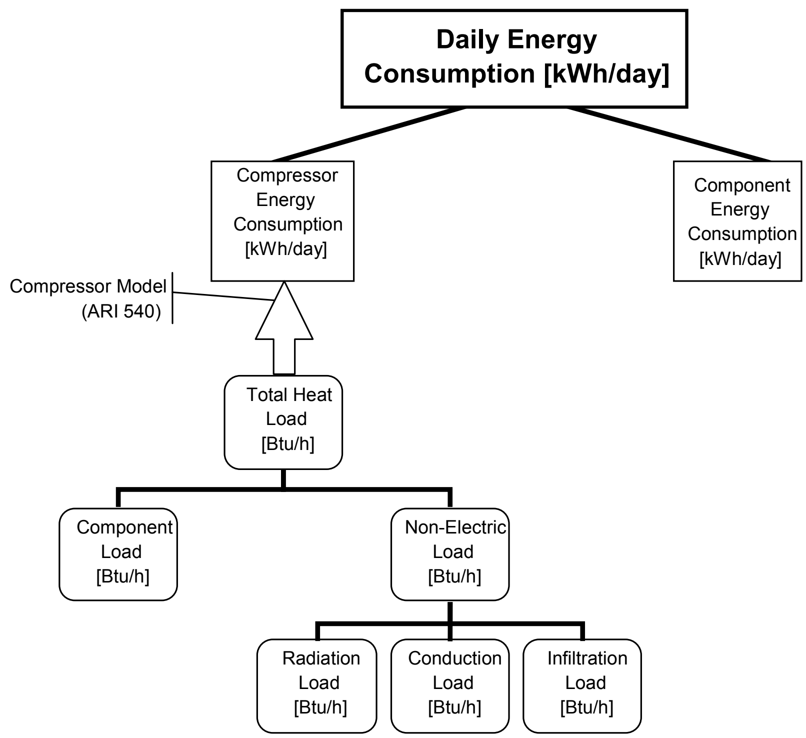

Figure 5.6.1 Composition of the Energy Consumption Model

5.6.6.1 Component Energy Consumption

Component energy consumption consists of calculated energy consumption of each of the system components that directly consumes energy.

Fan motor energy consumption is calculated by summing the power draw of each evaporator and condenser fan motor and multiplying the total motor power by the total running time over a 24-hour period.

Lighting energy consumption is calculated by summing the power draw of each lamp and ballast and multiplying the total by the total operating time of the lighting system over a 24-hour period. (This calculation assumes that lighting operates continuously at the baseline.) For cases where lighting controls and occupancy sensors have been implemented, a run-time reduction is used, based on the specifications for lighting controls and occupancy sensors in the commercial refrigeration equipment test procedure.

Daily defrost and drain heater energy consumption are calculated by summing the power draw of each defrost heater and drain heater and multiplying by the total time the case is in defrost operation over a 24-hour period.

Anti-sweat energy consumption is calculated by summing the power draw of each anti-sweat heater and multiplying by the total operating time of the heaters over a 24-hour period. (This calculation assumes that anti-sweat heaters run continuously, a position supported by manufacturer literature and interviews.)

Pan heater energy consumption is calculated by multiplying the power draw of each pan heater by the total operating time of the heater over a 24-hour period. The total operating time is calculated as the time it would take to evaporate all of the defrost meltwater.

5.6.6.2 Compressor Energy Consumption

Compressor energy consumption (CEC) is calculated from the total heat load and one of two compressor models: one version for remote condensing equipment and one for self-contained equipment. CEC for remote condensing equipment is calculated using default efficiency values from AHRI 1200. Table 1 in AHRI 1200 lists remote condensing compressor EER in Btu/W-h as a function of adjusted dew point temperature.

Adjusted dew point (ADP) temperature (°F) is calculated as:

$$ADP = SET - 2\ °F \text{ (for medium temperature)}$$

Eq. 5.2

$$ADP = SET - 3\ °F \text{ (for low/ice-cream temperature)}$$

Eq. 5.3

Where:

SET = the saturated evaporator temperature (°F).

Once ADP is calculated, Table 1 in AHRI 1200 is used to find the corresponding EER value. The CEC (kWh/day) is then calculated as:

$$CEC = Q_{tot}\ x\ (24 - t_{defrost}) / (EER \times 1000)$$

Eq. 5.4

Where:

Q_{tot} = the total heat load (Btu/hr), and
$t_{defrost}$ = the total defrost time in a 24-hour period (hr).

The CEC for self-contained equipment is calculated by using the compressor model described in section 6.4 of 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 SET and SCT. Compressor coefficients are available from compressor manufacturers. Similar to the method used for remote condensing equipment, the EER of any compressor can be determined given the SET and SCT values along with the 10 coefficients for the specific compressor model. Using Eq. 5.4 and the EER for the unit at the specific conditions being modeled, the CEC can be determined.

In the engineering analysis, DOE uses adjusted capacities for compressors modeled, rather than capacities at standard ASHRAE rating evaporator and condenser rating conditions. This is because the actual ASHRAE 72 test conditions for most commercial refrigeration equipment are not the same as standard compressor rating conditions, causing capacities at the modeled test conditions to differ from listed capacities. The compressor model then uses a look-up function to select the most appropriate compressor based on the total refrigeration load in the case and the compressor oversize factor from the baseline design specifications.

5.6.6.3 Component Load Model

The component load is the sum of the heat emitted by evaporator fan motors, lamps, defrost and drain heaters, and anti-sweat heater inside to the refrigerated space. Each component creates waste heat that is rejected to the refrigerated space and must be removed by the compressor.

DOE assumed that all electrical energy consumed by the evaporator fan motors ends up as heat inside the refrigerated space. In electric motors, friction present within the motor windings, bearings, and other mechanical components converts much of the input electrical energy into heat. The rest of the energy is used in moving air inside the case. This moving air is slowed by friction, and the kinetic energy of the air is converted into heat.

For lighting inside the refrigerated space, DOE assumed that all electrical energy consumed by the light fixtures ends up as heat inside the space. For lighting adjacent to the air curtain, DOE assumed that 50 percent of the electrical energy consumed ends up as heat inside the space. For fluorescent ballasts inside the refrigerated space, DOE assumed that all electrical energy that the ballasts consume ends up as heat inside the space. Ballasts outside the refrigerated space do not contribute any heat to the space. In cases in which occupancy sensors have been implemented as a design option, the heat inside the case resulting from lighting as calculated as above, but the run-time multiplier for the lighting is used to scale that heat load proportionately.

The phase change that occurs when defrost heaters melt the frost from evaporator coils consumes most of the electrical energy that supplied during a defrost period. Over a 24-hour period, the total heat of melting is determined by:

$$Q_{melt} = m_{frost} H_{f,water}$$

Eq. 5.5

Where:

Q_{melt} = the heat of melting (Btu/hr),
m_{frost} = the frost mass in a 24-hour period (lb/hr), and
$H_{f,water}$ = the heat of fusion of water (Btu/lb).

DOE assumed that all the electrical energy that defrost heaters consume, other than what is used to melt the frost, ends up as heat inside the refrigerated space. For drain heaters, DOE assumed that all electrical energy ends up as heat inside the refrigerated space.

DOE assumed that, on average, 70 percent of the electrical energy consumed by anti-sweat heaters adjacent to the refrigerated space (frame, rail, glass, sill, and air grille heaters) ends up as heat inside the space.

5.6.6.4 Radiation Load Model

The radiation heat load model accounts for the gray-body radiation between the warm surfaces of the surrounding environment (the test chamber) and the cold inner surfaces of the refrigerated space. For cases without doors, the net radiation is determined as:

$$Q_{rad} = \frac{\sigma\left(T_{room}^4 - T_{case}^4\right)}{\dfrac{1-\varepsilon_{room}}{\varepsilon_{room} A_{room}} + \dfrac{1}{A_{room} F_{case-room}} + \dfrac{1-\varepsilon_{case}}{\varepsilon_{case} A_{case}}}$$

Eq. 5.6

Where:

Q_{rad} = the net radiation load (Btu/hr),
σ = the Stefan-Boltzmann constant (Btu/hr-ft^2-°F^4),
T_{room} = the temperature of the room walls (°F),
T_{case} = the temperature of the case inner walls (°F),
ε_{room} = the emissivity of the room walls (dimensionless),
ε_{case} = the emissivity of the case inner walls (dimensionless),
A_{room} = the area of the room walls (ft^2),
A_{case} = the area of the interior of the case (ft^2), and
$F_{case\text{-}room}$ = the view factor from the case interior to the room walls (dimensionless).

DOE assumed that the wall temperatures of the case were in thermal equilibrium with the air temperature in the case, and that the wall temperatures of the room were in thermal equilibrium with the air temperature in the room. See Eq. 5.6 for numerical constants pertaining to the radiation model.

For glass doors and other glass, the net radiation is incorporated into the overall U-factor of the door (Table 5.6.10 through Table 5.6.14, and Eq. 5.7). See section 5.6.6.5 for a discussion of the calculation of the combined radiation and conduction loads for glass doors and other glass.

5.6.6.5 Conduction Load Model

The conduction load model accounts for the heat conducted through walls and doors. For solid walls and doors, the conduction is given by:

$$Q_{cond} = A_{walls} \frac{T_{room} - T_{case}}{\frac{1}{h_o} + \frac{d_{ins}}{k_{ins}} + \frac{1}{h_i}}$$

Eq. 5.7

Where:

A_{walls} = the area of the exterior of the case (ft^2),
h_o = the convective film coefficient on the outside of case walls (Btu/h-ft^2-°F),
h_i = the convective film coefficient on the inside of case walls (Btu/h-ft^2-°F),
d_{ins} = the insulation thickness (in.), and
k_{ins} = the insulation thermal conductivity (Btu-in/hr-ft^2-°F).

Because of its high thermal conductivity, the sheet metal that encloses the insulation has negligible effect on the conduction load, and therefore was not included in the calculation of conduction load. See Table 5.6.1 for numerical constants pertaining to the conduction model.

For glass doors and other glass, the overall U-factor of the door assembly or glass is based on data obtained thought WINDOW 5 calculations (Table 5.6.1 and Table 5.6.10 through Table 5.6.14). The combined radiation and conduction load for glass doors and other glass is calculated as:

$$Q_{glass} = U_{overall} A_{glass} \left(T_{room} - T_{case}\right)$$

Eq. 5.8

Where:

$U_{overall}$ = the overall U-factor, including convection and radiation (Btu/h-ft^2-°F), and
A_{glass} = the area of the glass (ft^2).

5.6.6.6 Infiltration Load Model

In the engineering analysis, DOE used values for infiltrated air (in lb/hr) for all equipment classes. DOE estimated infiltrated air by using manufacturers' detailed specification sheets, recognizing that infiltration load is the only load component that cannot be directly calculated. These estimates were directly calculated for some equipment classes, and then extended for use in the remaining primary classes. DOE then used the infiltrated air mass data to calculate a sensible heat load and latent heat load due to infiltration, based on the thermodynamic properties of the water in the air as well as the assumed ambient and operating conditions. The sum of these two values constituted the portion of the case heat load attributed to ambient air infiltration.

5.7 COST-EFFICIENCY CURVES

The result of the engineering analysis is a set of cost-efficiency curves. DOE developed 25 curves representing the directly analyzed primary equipment classes, using the baseline specifications and design options described above. (See appendix 5A for details.) The methodology for developing curves started with determining the baseline energy consumption and MPC using the methodology discussed in this chapter. To develop engineering efficiency levels above the baseline, DOE implemented design options in order from highest to lowest return on cost. Only one design option was implemented at each design option level, except for LED lighting and lighting occupancy sensors, which, in some classes, were implemented simultaneously due to synergistic effects within the energy consumption model (See section 5.6.5.1 for details.) Design options were implemented until all equipment classes reached the max-tech level based upon the available design options.

The 25 cost-efficiency curves are shown in Figure 5.7.1 through Figure 5.7.25 in the form of daily energy consumption versus MSP. Supporting data for each primary class, including CDEC, MPC, MSP, and the design option ordering used in DOE's analysis, is shown in Table 5.7.2 through Table 5.7.26. Table 5.7.1 shows a list of the 25 analyzed equipment classes and their corresponding figure, table, and page numbers.

Table 5.7.1 Figure, Table, and Page Numbers for Cost-Efficiency Results

Equipment Class	Figure	Table	Page Number
VOP.RC.M	Figure 5.7.1	Table 5.7.2	5-39
VOP.RC.L	Figure 5.7.2	Table 5.7.3	5-40
VOP.SC.M	Figure 5.7.3	Table 5.7.4	5-41
SVO.RC.M	Figure 5.7.4	Table 5.7.5	5-42
SVO.SC.M	Figure 5.7.5	Table 5.7.6	5-43
HZO.RC.M	Figure 5.7.6	Table 5.7.7	5-44
HZO.RC.L	Figure 5.7.7	Table 5.7.8	5-45
HZO.SC.M	Figure 5.7.8	Table 5.7.9	5-46
HZO.SC.L	Figure 5.7.9	Table 5.7.10	5-47
VCT.RC.M	Figure 5.7.10	Table 5.7.11	5-48
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VCT.SC.M	Figure 5.7.12	Table 5.7.13	5-50
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VCS.SC.I	Figure 5.7.17	Table 5.7.18	5-55
HCT.SC.M	Figure 5.7.18	Table 5.7.19	5-56
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SOC.RC.M	Figure 5.7.23	Table 5.7.24	5-61
SOC.SC.M	Figure 5.7.24	Table 5.7.25	5-62
PD.SC.M	Figure 5.7.25	Table 5.7.26	5-63

As stated above, DOE used the cost-efficiency curves from the engineering analysis as an input to the life-cycle cost analysis to determine the overall cost to the customer of purchasing, installing, maintaining, and using a given piece of commercial refrigeration equipment over the duration of its lifetime (chapter 8 of the TSD).

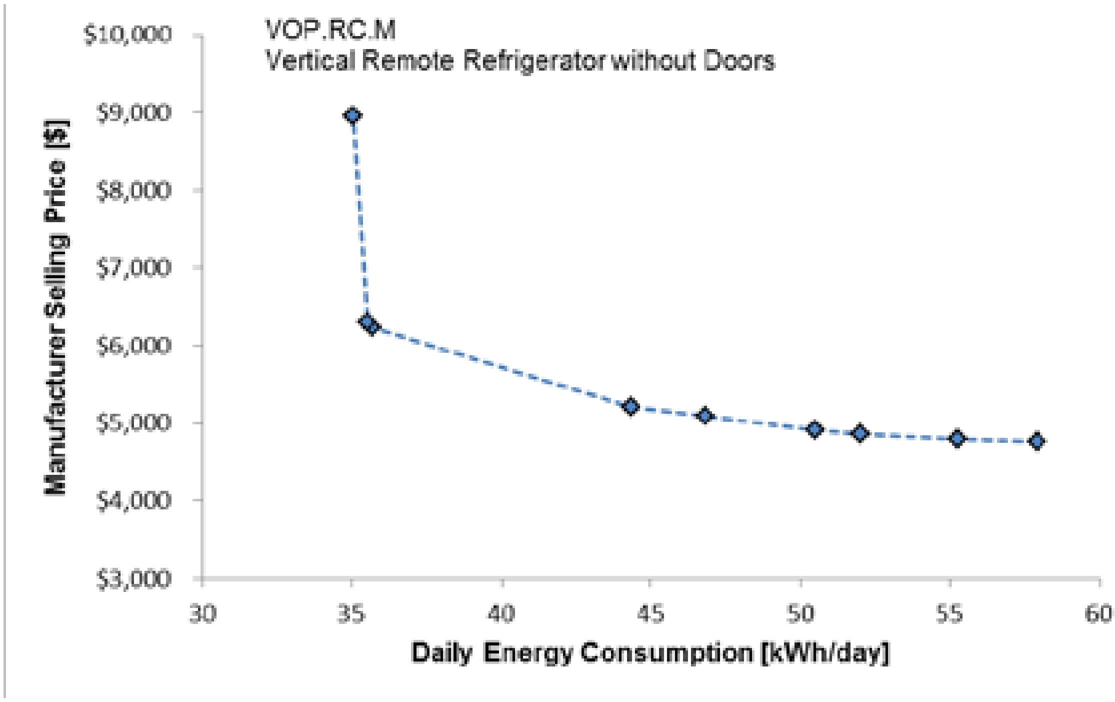

Figure 5.7.1 Cost-Efficiency Curve for the VOP.RC.M Equipment Class

Table 5.7.2 Cost-Efficiency Data for the VOP.RC.M Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	57.90	3,173.79	4,759.07	Baseline
AD2	55.28	3,198.60	4,794.31	AD1 + Permanent Split Cap. Evap. Fan Motor
AD3	51.99	3,251.34	4,869.20	AD2 + Brushless DC Evap. Fan Motor
AD4	50.52	3,280.30	4,910.32	AD3 + Super T8 Lighting
AD5	46.84	3,404.38	5,086.52	AD4 + Night Curtains
AD6	44.33	3,490.44	5,208.72	AD5 + Enhanced-UA Evaporator Coil
AD7	35.71	4,207.18	6,226.49	AD6 + LED Lighting with Occupancy Sensors
AD8	35.51	4,252.31	6,290.57	AD7 + Additional 1/2" Insulation
AD9	35.06	6,123.48	8,947.63	AD8 + Vacuum Insulated Panels

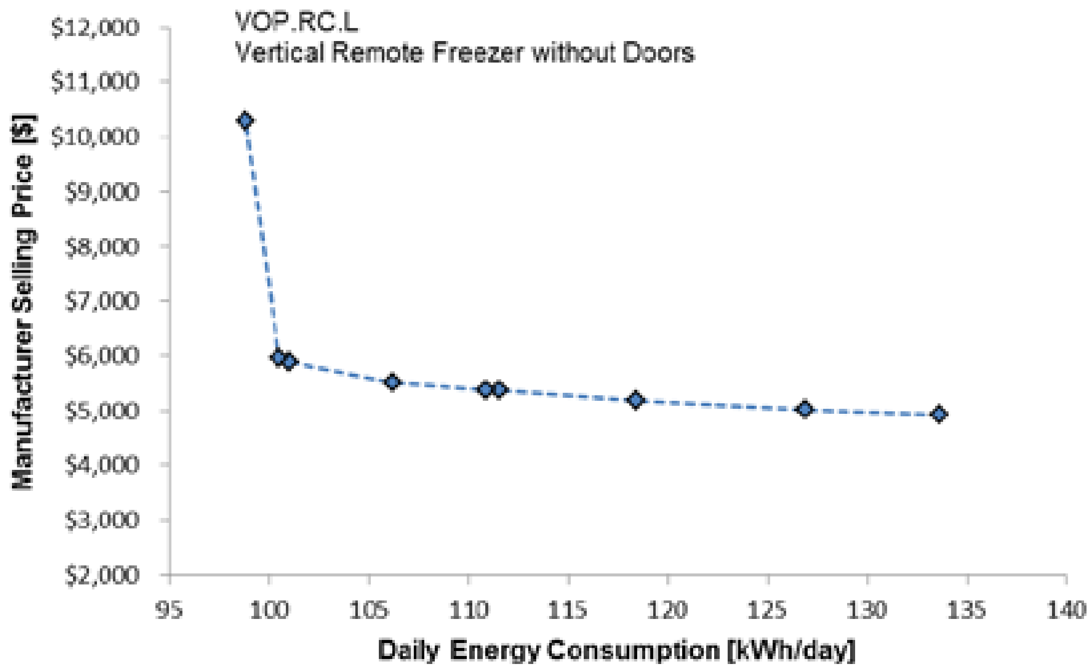

Figure 5.7.2 Cost-Efficiency Curve for the VOP.RC.L Equipment Class

Table 5.7.3 Cost-Efficiency Data for the VOP.RC.L Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	133.60	3,290.35	4,924.60	Baseline
AD2	126.90	3,348.26	5,006.83	AD1 + Permanent Split Cap. Evap. Fan Motor
AD3	118.44	3,471.32	5,181.56	AD2 + Brushless DC Evap. Fan Motor
AD4	111.58	3,595.40	5,357.77	AD3 + Night Curtains
AD5	110.92	3,607.81	5,375.39	AD4 + Super T8 Lighting
AD6	106.22	3,709.13	5,519.26	AD5 + Enhanced-UA Evaporator Coil
AD7	101.03	3,957.44	5,871.86	AD6 + LED Lighting with Occupancy Sensors
AD8	100.51	4,007.48	5,942.92	AD7 + Additional 1/2" Insulation
AD9	98.87	7,061.66	10,279.86	AD8 + Vacuum Insulated Panels

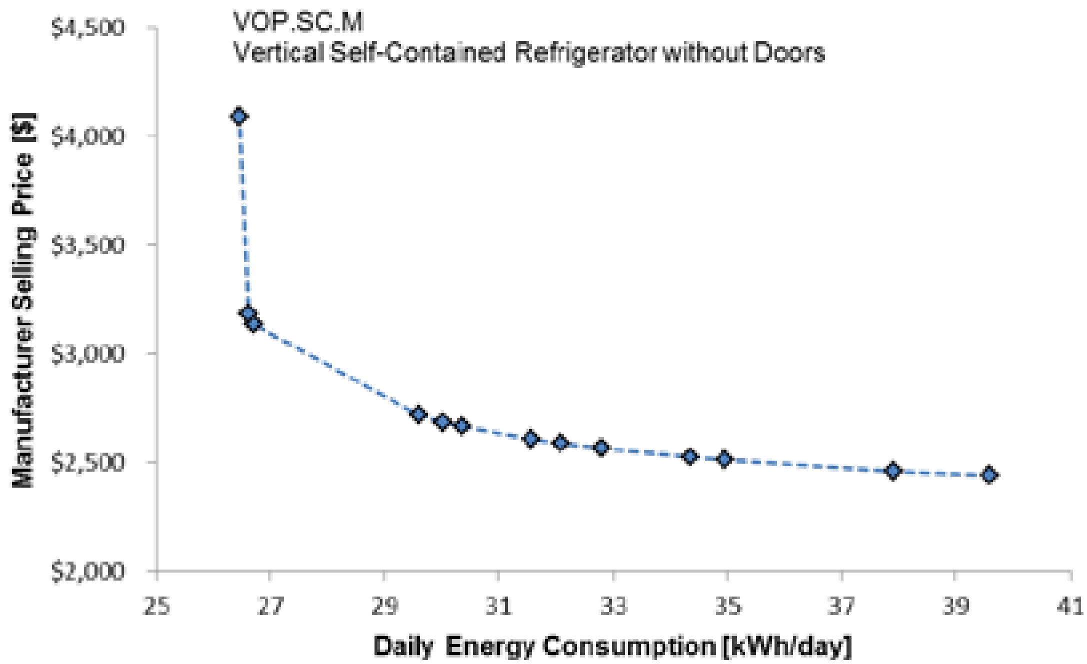

Figure 5.7.3 Cost-Efficiency Curve for the VOP.SC.M Equipment Class

Table 5.7.4 Cost-Efficiency Data for the VOP.SC.M Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	39.60	1,669.61	2,439.74	Baseline
AD2	37.91	1,682.53	2,458.10	AD1 + High-Eff. Reciprocating Compressor
AD3	34.96	1,721.42	2,513.31	AD2 + Enhanced-UA Condenser Coil
AD4	34.35	1,730.72	2,526.53	AD3 + Permanent Split Cap. Evap. Fan Motor
AD5	32.81	1,759.75	2,567.74	AD4 + Enhanced-UA Evaporator Coil
AD6	32.09	1,774.74	2,589.03	AD5 + Brushless DC Evap. Fan Motor
AD7	31.58	1,785.60	2,604.45	AD6 + Super T8 Lighting
AD8	30.37	1,826.96	2,663.18	AD7 + Night Curtains
AD9	30.03	1,839.37	2,680.80	AD8 + Permanent Split Cap. Cond. Fan Motor
AD10	29.60	1,865.74	2,718.25	AD9 + Brushless DC Cond. Fan Motor
AD11	26.70	2,160.66	3,137.04	AD10 + LED Lighting with Occupancy Sensors
AD12	26.62	2,190.93	3,180.03	AD11 + Additional 1/2" Insulation
AD13	26.46	2,829.13	4,086.26	AD12 + Vacuum Insulated Panels

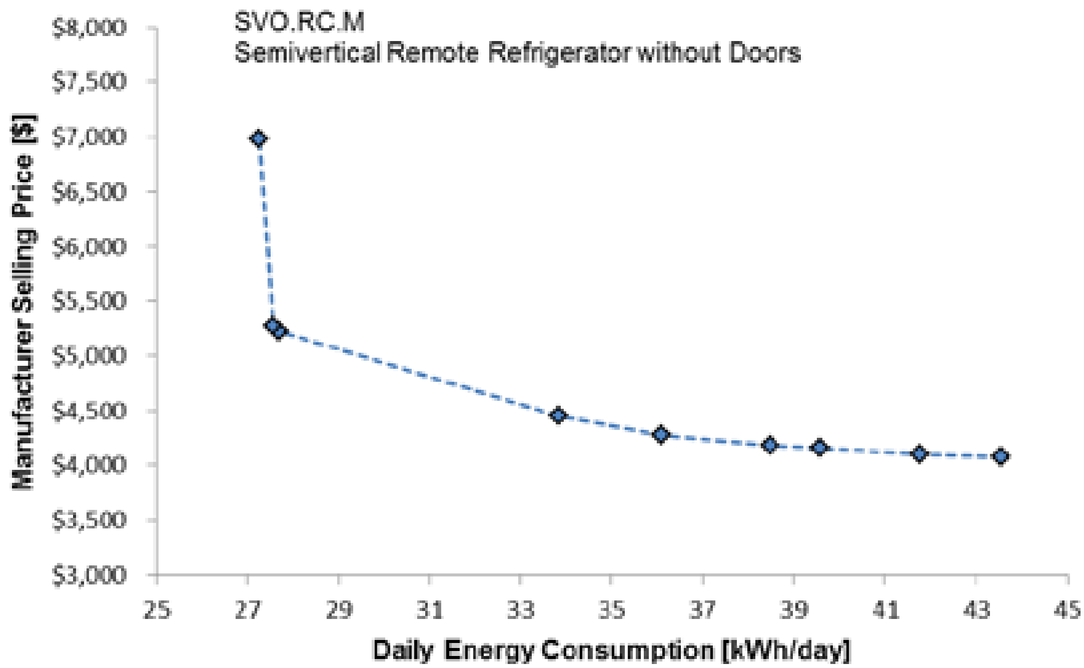

Figure 5.7.4 Cost-Efficiency Curve for the SVO.RC.M Equipment Class

Table 5.7.5 Cost-Efficiency Data for the SVO.RC.M Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	43.56	2,775.31	4,080.77	Baseline
AD2	41.78	2,791.86	4,104.26	AD1 + Permanent Split Cap. Evap. Fan Motor
AD3	39.58	2,827.02	4,154.19	AD2 + Brushless DC Evap. Fan Motor
AD4	38.47	2,847.70	4,183.56	AD3 + Super T8 Lighting
AD5	36.11	2,907.69	4,268.75	AD4 + Enhanced-UA Evaporator Coil
AD6	33.85	3,031.78	4,444.96	AD5 + Night Curtains
AD7	27.71	3,578.80	5,221.73	AD6 + LED Lighting with Occupancy Sensors
AD8	27.57	3,615.85	5,274.33	AD7 + Additional 1/2" Insulation
AD9	27.26	4,816.22	6,978.85	AD8 + Vacuum Insulated Panels

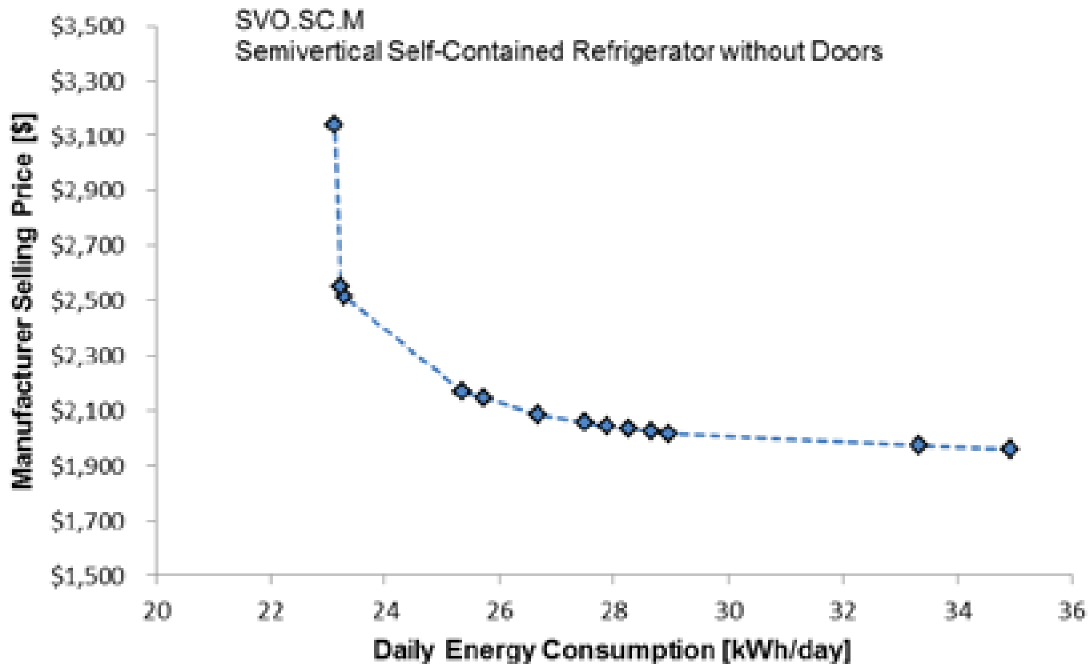

Figure 5.7.5 Cost-Efficiency Curve for the SVO.SC.M Equipment Class

Table 5.7.6 Cost-Efficiency Data for the SVO.SC.M Equipment Class

Design Option Level	**Calculated Daily Energy Consumption** ***kWh/day***	**Manufacturer Production Cost** ***$***	**Manufacturer Selling Price** ***$***	**Design Option Added Above the Baseline**
AD1	34.93	1,350.11	1,959.71	Baseline
AD2	33.33	1,359.78	1,973.44	AD1 + High-Eff. Reciprocating Compressor
AD3	28.96	1,389.49	2,015.63	AD2 + Enhanced-UA Condenser Coil
AD4	28.66	1,394.14	2,022.24	AD3 + Permanent Split Cap. Evap. Fan Motor
AD5	28.27	1,401.64	2,032.89	AD4 + Super T8 Lighting
AD6	27.89	1,409.14	2,043.53	AD5 + Brushless DC Evap. Fan Motor
AD7	27.50	1,417.41	2,055.28	AD6 + Permanent Split Cap. Cond. Fan Motor
AD8	26.67	1,439.59	2,086.78	AD7 + Enhanced-UA Evaporator Coil
AD9	25.74	1,480.96	2,145.51	AD8 + Night Curtains
AD10	25.36	1,498.54	2,170.48	AD9 + Brushless DC Cond. Fan Motor
AD11	23.29	1,739.04	2,512.00	AD10 + LED Lighting with Occupancy Sensors
AD12	23.24	1,766.62	2,551.16	AD11 + Additional 1/2" Insulation
AD13	23.12	2,181.67	3,140.52	AD12 + Vacuum Insulated Panels

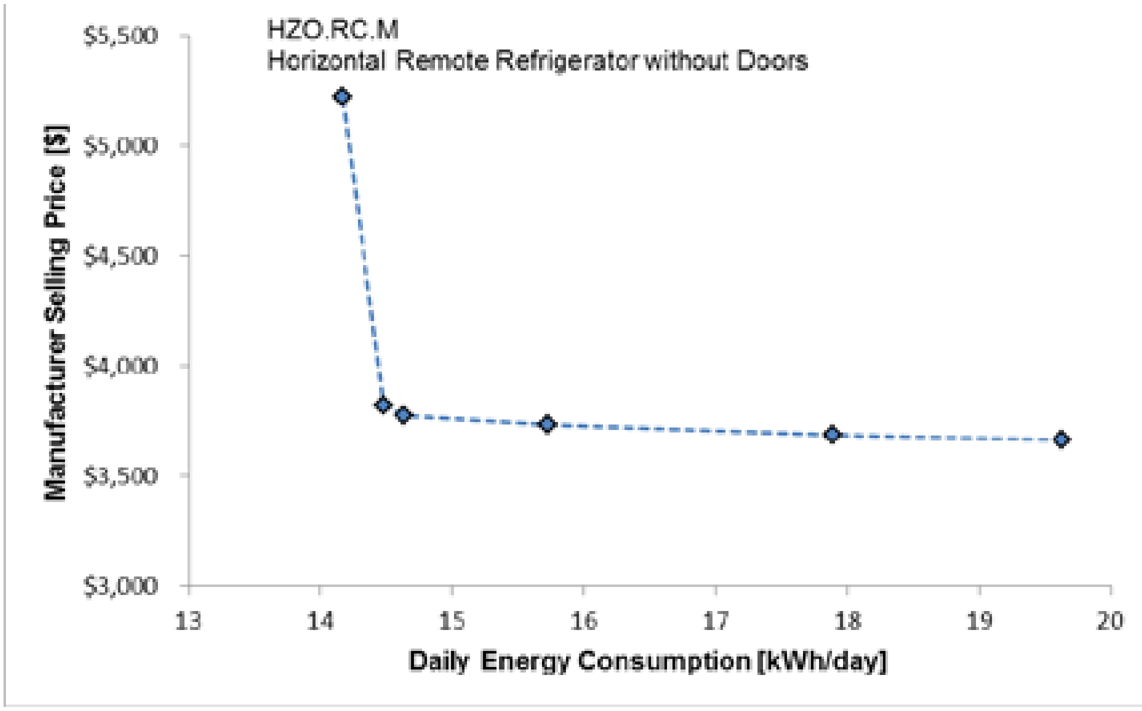

Figure 5.7.6 Cost-Efficiency Curve for the HZO.RC.M Equipment Class

Table 5.7.7 Cost-Efficiency Data for the HZO.RC.M Equipment Class

Design Option Level	**Calculated Daily Energy Consumption** ***kWh/day***	**Manufacturer Production Cost** ***$***	**Manufacturer Selling Price** ***$***	**Design Option Added Above the Baseline**
AD1	19.63	2,498.58	3,661.47	Baseline
AD2	17.89	2,515.13	3,684.97	AD1 + Permanent Split Cap. Evap. Fan Motor
AD3	15.73	2,550.29	3,734.89	AD2 + Brushless DC Evap. Fan Motor
AD4	14.64	2,577.21	3,773.12	AD3 + Enhanced-UA Evaporator Coil
AD5	14.48	2,611.65	3,822.03	AD4 + Additional 1/2" Insulation
AD6	14.17	3,596.11	5,219.96	AD5 + Vacuum Insulated Panels

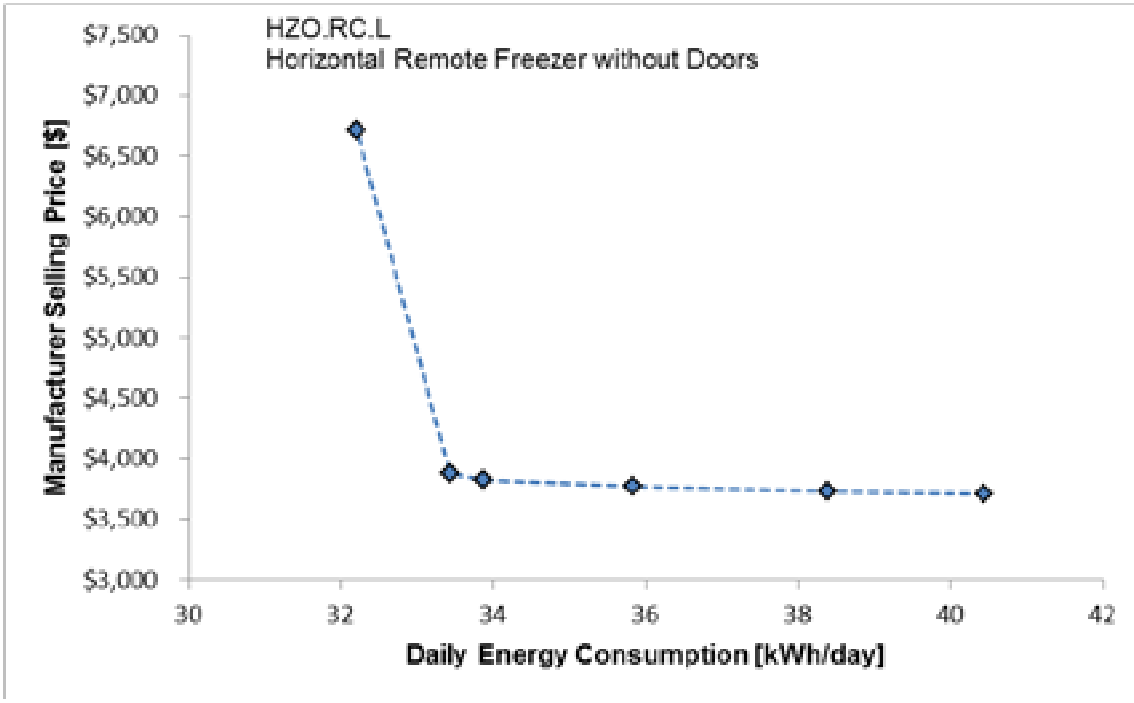

Figure 5.7.7 Cost-Efficiency Curve for the HZO.RC.L Equipment Class

Table 5.7.8 Cost-Efficiency Data for the HZO.RC.L Equipment Class

Design Option Level	**Calculated Daily Energy Consumption** ***kWh/day***	**Manufacturer Production Cost** ***$***	**Manufacturer Selling Price** ***$***	**Design Option Added Above the Baseline**
AD1	40.44	2,530.49	3,706.78	Baseline
AD2	38.39	2,547.03	3,730.27	AD1 + Permanent Split Cap. Evap. Fan Motor
AD3	35.84	2,582.19	3,780.20	AD2 + Brushless DC Evap. Fan Motor
AD4	33.87	2,616.15	3,828.42	AD3 + Enhanced-UA Evaporator Coil
AD5	33.43	2,656.63	3,885.90	AD4 + Additional 1/2" Insulation
AD6	32.22	4,649.07	6,715.17	AD5 + Vacuum Insulated Panels

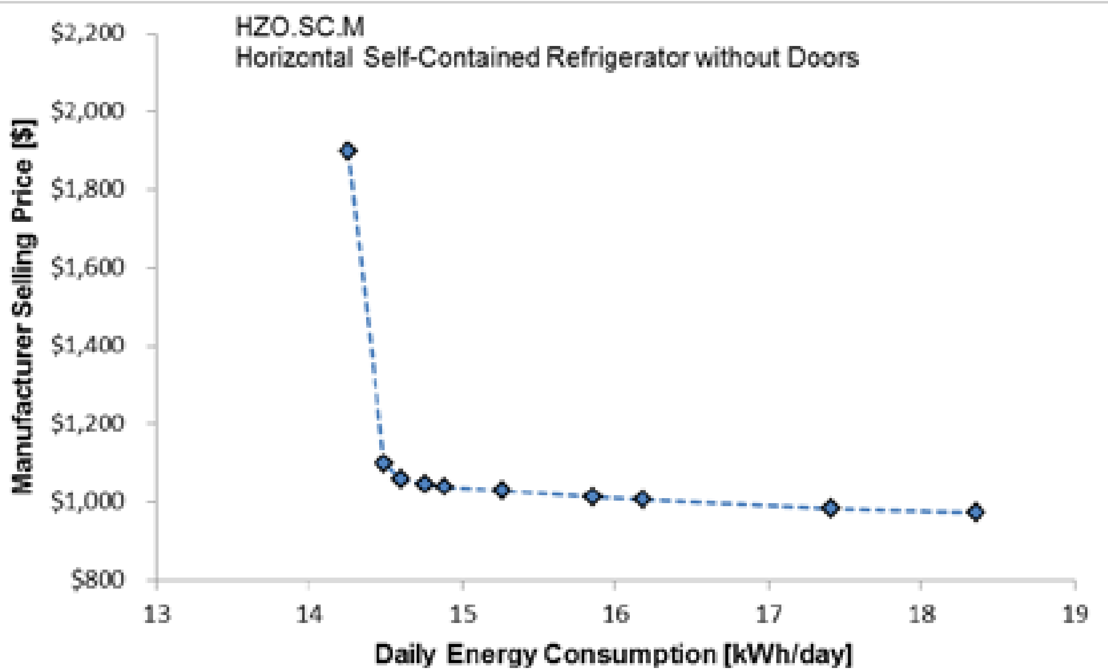

Figure 5.7.8 Cost-Efficiency Curve for the HZO.SC.M Equipment Class

Table 5.7.9 Cost-Efficiency Data for the HZO.SC.M Equipment Class

Design Option Level	**Calculated Daily Energy Consumption** ***kWh/day***	**Manufacturer Production Cost** ***$***	**Manufacturer Selling Price** ***$***	**Design Option Added Above the Baseline**
AD1	18.36	670.82	972.84	Baseline
AD2	17.41	678.06	983.11	AD1 + High-Eff. Reciprocating Compressor
AD3	16.18	693.96	1,005.69	AD2 + Enhanced-UA Condenser Coil
AD4	15.86	698.61	1,012.30	AD3 + Permanent Split Cap. Evap. Fan Motor
AD5	15.26	710.48	1,029.15	AD4 + Enhanced-UA Evaporator Coil
AD6	14.89	717.98	1,039.79	AD5 + Brushless DC Evap. Fan Motor
AD7	14.76	722.63	1,046.40	AD6 + Permanent Split Cap. Cond. Fan Motor
AD8	14.60	730.13	1,057.05	AD7 + Brushless DC Cond. Fan Motor
AD9	14.49	759.49	1,098.74	AD8 + Additional ½-inch Insulation
AD10	14.26	1,322.59	1,898.34	AD9 + Vacuum Insulated Panels

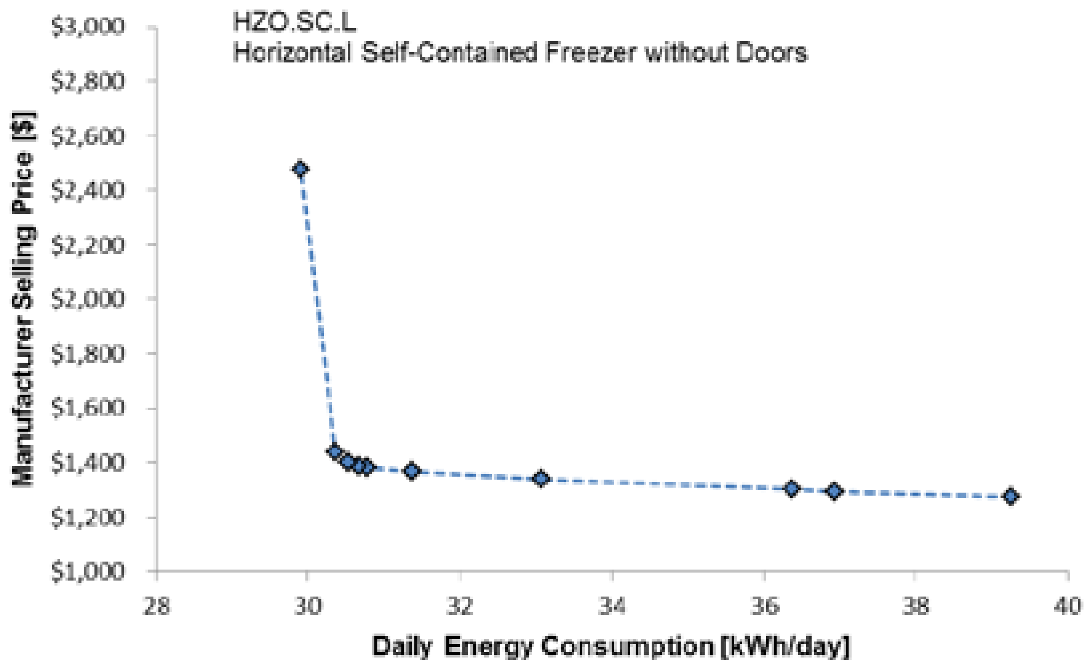

Figure 5.7.9 Cost-Efficiency Curve for the HZO.SC.L Equipment Class

Table 5.7.10 Cost-Efficiency Data for the HZO.SC.L Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	39.25	882.63	1,273.60	Baseline
AD2	36.93	897.42	1,294.60	AD1 + High-Eff. Reciprocating Compressor
AD3	36.38	901.55	1,300.47	AD2 + Permanent Split Cap. Evap. Fan Motor
AD4	33.08	929.41	1,340.02	AD3 + Enhanced-UA Condenser Coil
AD5	31.37	950.20	1,369.55	AD4 + Enhanced-UA Evaporator Coil
AD6	30.78	958.99	1,382.03	AD5 + Brushless DC Evap. Fan Motor
AD7	30.67	963.64	1,388.64	AD6 + Permanent Split Cap. Cond. Fan Motor
AD8	30.54	971.14	1,399.28	AD7 + Brushless DC Cond. Fan Motor
AD9	30.37	1,000.25	1,440.62	AD8 + Additional ½-inch Insulation
AD10	29.91	1,730.09	2,476.99	AD9 + Vacuum Insulated Panels

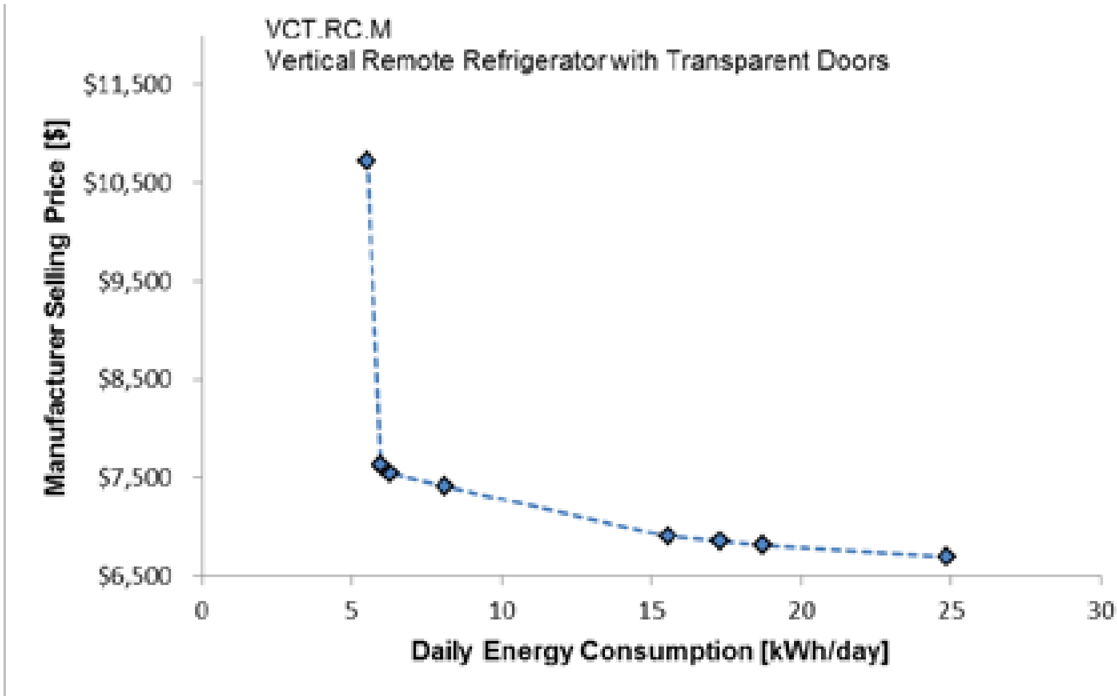

Figure 5.7.10 Cost-Efficiency Curve for the VCT.RC.M Equipment Class

Table 5.7.11 Cost-Efficiency Data for the VCT.RC.M Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	24.85	4,548.80	6,694.37	Baseline
AD2	18.70	4,636.16	6,818.41	AD1 + LED Lighting
AD3	17.30	4,659.42	6,851.45	AD2 + Permanent Split Cap. Evap. Fan Motor
AD4	15.56	4,696.91	6,904.68	AD3 + Brushless DC Evap. Fan Motor
AD5	8.10	5,057.76	7,417.09	AD4 + High-Performance Door
AD6	6.26	5,148.24	7,545.57	AD5 + LED Lighting with Occupancy Sensors
AD7	6.01	5,196.99	7,614.80	AD6 + Additional ½-inch Insulation
AD8	5.97	5,214.09	7,639.08	AD7 + Enhanced-UA Evaporator Coil
AD9	5.49	7,386.46	10,723.85	AD8 + Vacuum Insulated Panels

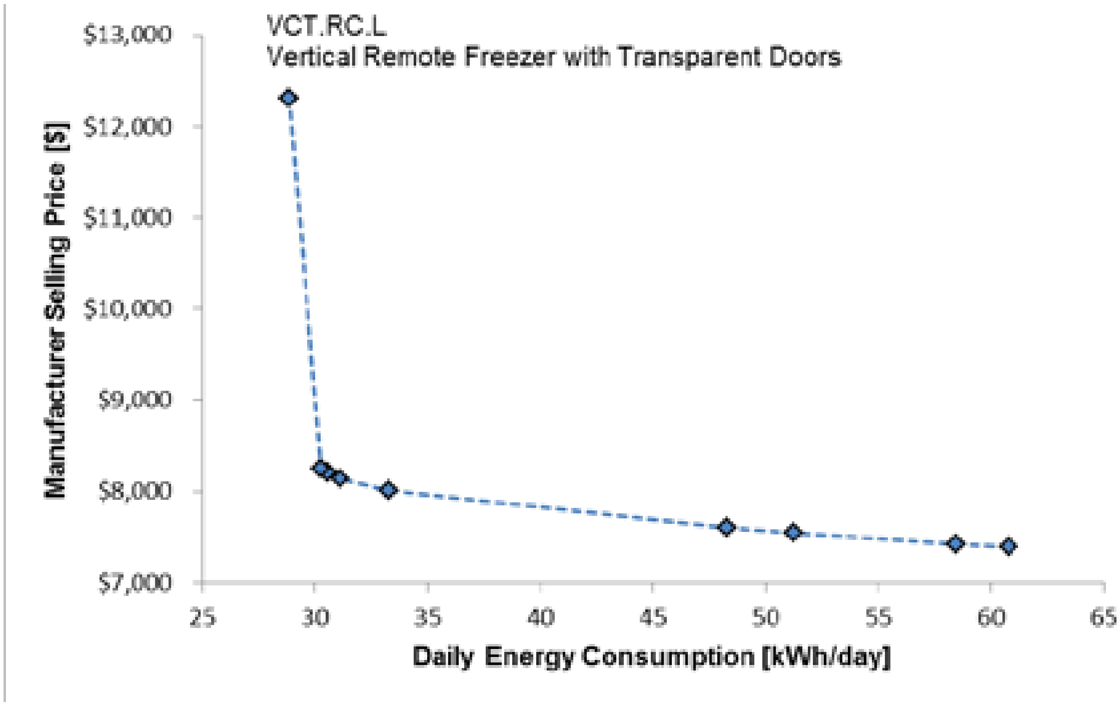

Figure 5.7.11 Cost-Efficiency Curve for the VCT.RC.L Equipment Class

Table 5.7.12 Cost-Efficiency Data for the VCT.RC.L Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	60.84	5,036.82	7,387.35	Baseline
AD2	58.47	5,057.50	7,416.72	AD1 + Permanent Split Cap. Evap. Fan Motor
AD3	51.25	5,144.85	7,540.76	AD2 + LED Lighting
AD4	48.31	5,188.80	7,603.17	AD3 + Brushless DC Evap. Fan Motor
AD5	33.27	5,477.48	8,013.09	AD4 + High-Performance Door
AD6	31.13	5,567.96	8,141.58	AD5 + LED Lighting with Occupancy Sensors
AD7	30.58	5,616.20	8,210.08	AD6 + Additional ½-inch Insulation
AD8	30.29	5,646.64	8,253.30	AD7 + Enhanced-UA Evaporator Coil
AD9	28.85	8,499.95	12,305.00	AD8 + Vacuum Insulated Panels

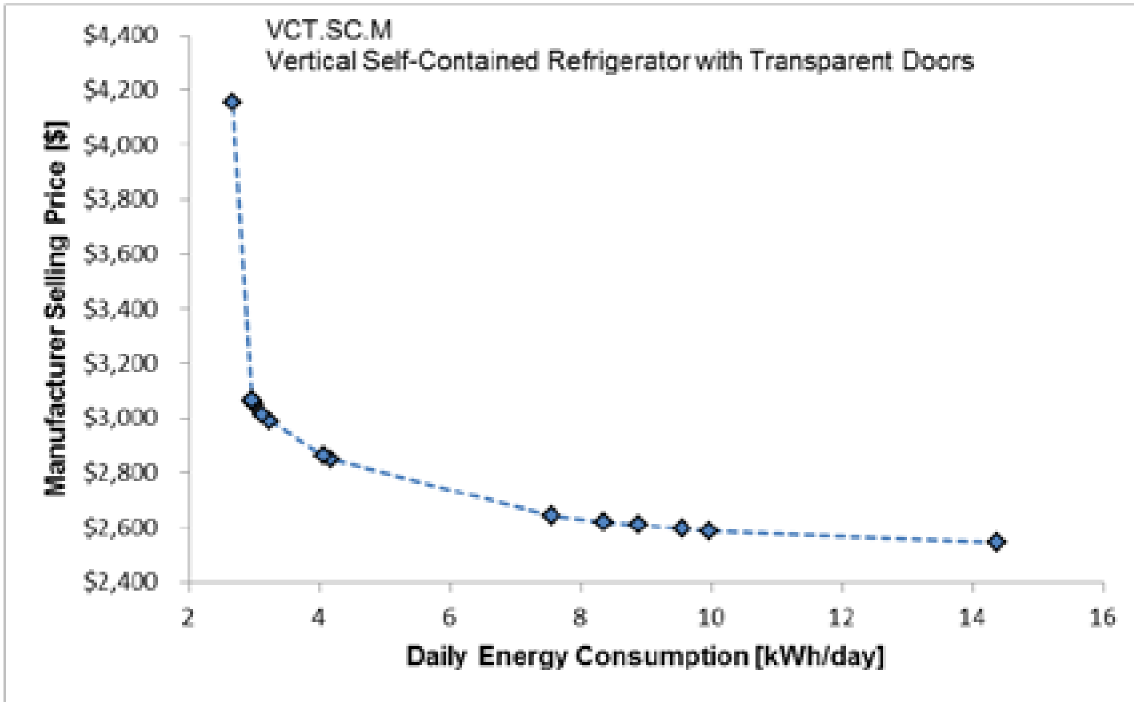

Figure 5.7.12 Cost-Efficiency Curve for the VCT.SC.M Equipment Class

Table 5.7.13 Cost-Efficiency Data for the VCT.SC.M Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	14.38	1,749.80	2,546.52	Baseline
AD2	9.98	1,778.22	2,586.88	AD1 + LED Lighting
AD3	9.56	1,783.91	2,594.96	AD2 + High-Eff. Reciprocating Compressor
AD4	8.88	1,793.22	2,608.17	AD3 + Permanent Split Cap. Evap. Fan Motor
AD5	8.36	1,802.46	2,621.29	AD4 + Enhanced-UA Condenser Coil
AD6	7.56	1,817.45	2,642.59	AD5 + Brushless DC Evap. Fan Motor
AD7	4.18	1,961.79	2,847.55	AD6 + High-Performance Door
AD8	4.08	1,971.10	2,860.76	AD7 + Permanent Split Cap. Cond. Fan Motor
AD9	3.24	2,061.58	2,989.25	AD8 + LED Lighting with Occupancy Sensors
AD10	3.13	2,076.57	3,010.54	AD9 + Brushless DC Cond. Fan Motor
AD11	2.98	2,108.40	3,055.73	AD10 + Additional ½-inch Insulation
AD12	2.97	2,115.29	3,065.52	AD11 + Enhanced-UA Evaporator Coil
AD13	2.68	2,882.44	4,154.88	AD12 + Vacuum Insulated Panels

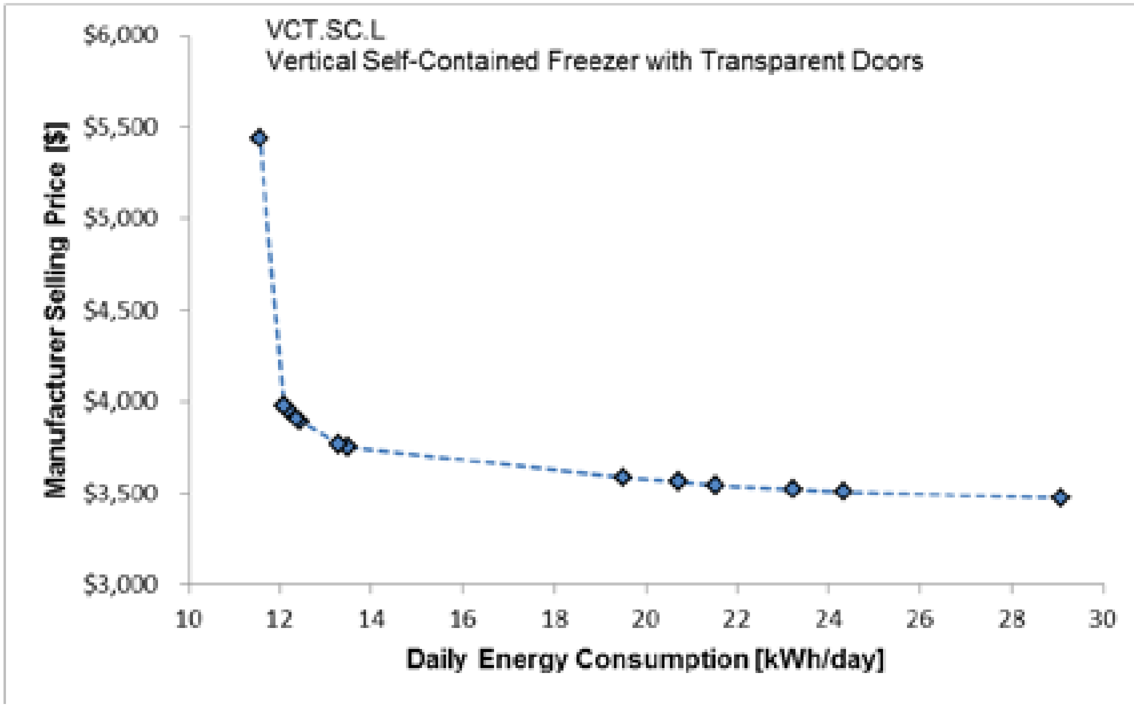

Figure 5.7.13 Cost-Efficiency Curve for the VCT.SC.L Equipment Class

Table 5.7.14 Cost-Efficiency Data for the VCT.SC.L Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	29.09	2,399.20	3,468.66	Baseline
AD2	24.32	2,427.62	3,509.03	AD1 + LED Lighting
AD3	23.23	2,435.89	3,520.78	AD2 + Permanent Split Cap. Evap. Fan Motor
AD4	21.51	2,451.85	3,543.43	AD3 + Enhanced-UA Condenser Coil
AD5	20.71	2,463.27	3,559.65	AD4 + High-Eff. Reciprocating Compressor
AD6	19.51	2,480.85	3,584.62	AD5 + Brushless DC Evap. Fan Motor
AD7	13.48	2,596.32	3,748.59	AD6 + High-Performance Door
AD8	13.30	2,608.23	3,765.49	AD7 + Enhanced-UA Evaporator Coil
AD9	12.44	2,698.71	3,893.98	AD8 + LED Lighting with Occupancy Sensors
AD10	12.37	2,708.02	3,907.19	AD9 + Permanent Split Cap. Cond. Fan Motor
AD11	12.18	2,739.84	3,952.38	AD10 + Additional ½-inch Insulation
AD12	12.09	2,754.84	3,973.68	AD11 + Brushless DC Cond. Fan Motor
AD13	11.57	3,786.27	5,438.31	AD12 + Vacuum Insulated Panels

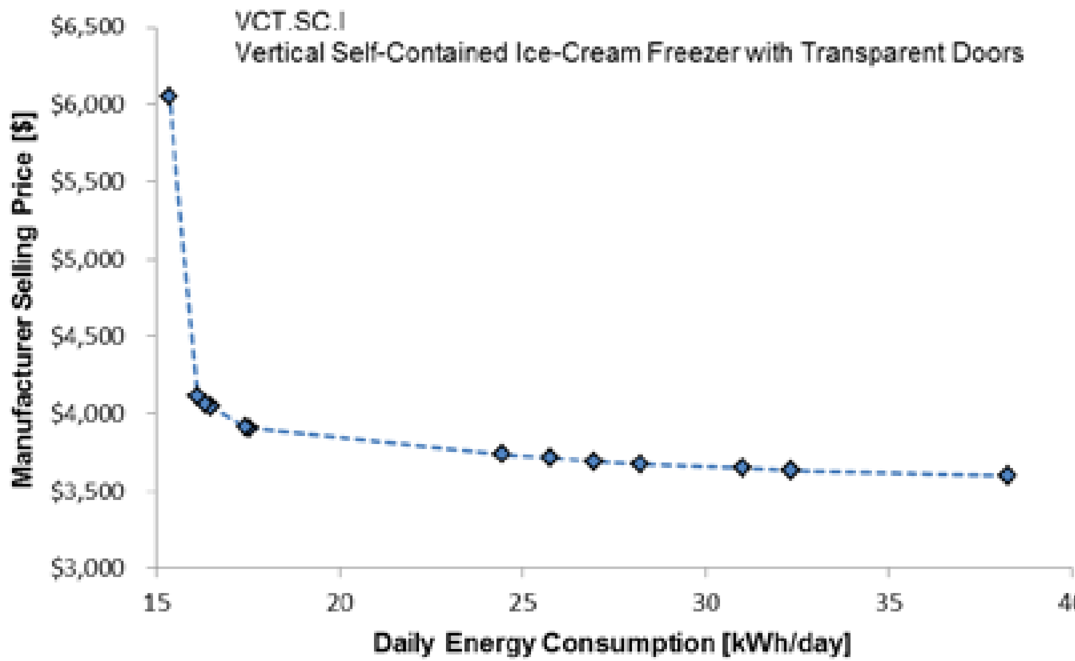

Figure 5.7.14 Cost-Efficiency Curve for the VCT.SC.I Equipment Class

Table 5.7.15 Cost-Efficiency Data for the VCT.SC.I Equipment Class

Design Option Level	**Calculated Daily Energy Consumption** ***kWh/day***	**Manufacturer Production Cost** ***$***	**Manufacturer Selling Price** ***$***	**Design Option Added Above the Baseline**
AD1	38.26	2,485.76	3,594.62	Baseline
AD2	32.35	2,514.18	3,634.99	AD1 + LED Lighting
AD3	31.03	2,522.46	3,646.73	AD2 + Permanent Split Cap. Evap. Fan Motor
AD4	28.23	2,540.95	3,673.00	AD3 + Enhanced-UA Condenser Coil
AD5	26.98	2,554.75	3,692.60	AD4 + Enhanced-UA Evaporator Coil
AD6	25.76	2,568.82	3,712.57	AD5 + High-Eff. Reciprocating Compressor
AD7	24.45	2,586.40	3,737.53	AD6 + Brushless DC Evap. Fan Motor
AD8	17.57	2,701.87	3,901.50	AD7 + High-Performance Door
AD9	17.45	2,711.17	3,914.72	AD8 + Permanent Split Cap. Cond. Fan Motor
AD10	16.51	2,801.66	4,043.20	AD9 + LED Lighting with Occupancy Sensors
AD11	16.36	2,816.65	4,064.49	AD10 + Brushless DC Cond. Fan Motor
AD12	16.14	2,848.99	4,110.41	AD11 + Additional ½-inch Insulation
AD13	15.37	4,216.21	6,051.86	AD12 + Vacuum Insulated Panels

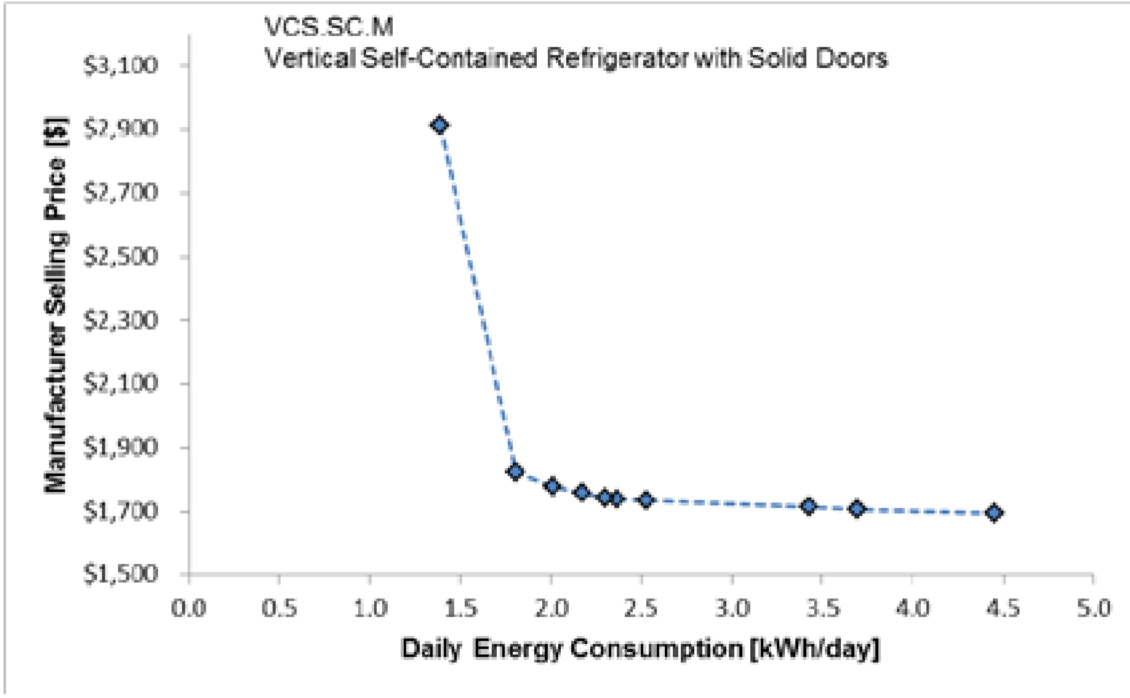

Figure 5.7.15 Cost-Efficiency Curve for the VCS.SC.M Equipment Class

Table 5.7.16 Cost-Efficiency Data for the VCS.SC.M Equipment Class

Design Option Level	**Calculated Daily Energy Consumption** ***kWh/day***	**Manufacturer Production Cost** ***$***	**Manufacturer Selling Price** ***$***	**Design Option Added Above the Baseline**
AD1	4.45	1,150.32	1,694.25	Baseline
AD2	3.70	1,159.63	1,707.47	AD1 + Permanent Split Cap. Evap. Fan Motor
AD3	3.42	1,163.41	1,712.84	AD2 + Enhanced-UA Condenser Coil
AD4	2.53	1,178.41	1,734.13	AD3 + Brushless DC Evap. Fan Motor
AD5	2.36	1,182.49	1,739.93	AD4 + High-Eff. Reciprocating Compressor
AD6	2.30	1,185.31	1,743.94	AD5 + Enhanced-UA Evaporator Coil
AD7	2.17	1,194.62	1,757.16	AD6 + Permanent Split Cap. Cond. Fan Motor
AD8	2.01	1,209.61	1,778.45	AD7 + Brushless DC Cond. Fan Motor
AD9	1.81	1,241.44	1,823.64	AD8 + Additional ½-inch Insulation
AD10	1.39	2,008.59	2,912.99	AD9 + Vacuum Insulated Panels

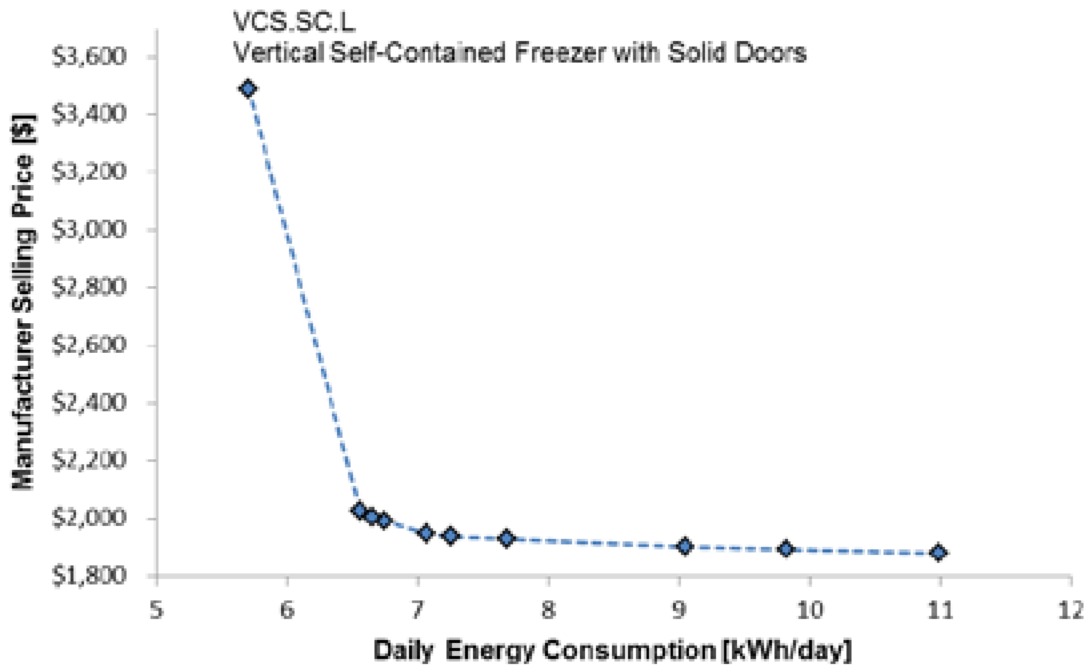

Figure 5.7.16 Cost-Efficiency Curve for the VCS.SC.L Equipment Class

Table 5.7.17 Cost-Efficiency Data for the VCS.SC.L Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	11.00	1,281.21	1,880.11	Baseline
AD2	9.82	1,289.48	1,891.86	AD1 + Permanent Split Cap. Evap. Fan Motor
AD3	9.05	1,296.54	1,901.88	AD2 + Enhanced-UA Condenser Coil
AD4	7.69	1,314.12	1,926.84	AD3 + Brushless DC Evap. Fan Motor
AD5	7.26	1,323.06	1,939.54	AD4 + High-Eff. Reciprocating Compressor
AD6	7.07	1,328.33	1,947.02	AD5 + Enhanced-UA Evaporator Coil
AD7	6.75	1,360.15	1,992.21	AD6 + Additional ½-inch Insulation
AD8	6.66	1,369.46	2,005.42	AD7 + Permanent Split Cap. Cond. Fan Motor
AD9	6.56	1,384.45	2,026.71	AD8 + Brushless DC Cond. Fan Motor
AD10	5.71	2,415.88	3,491.34	AD9 + Vacuum Insulated Panels

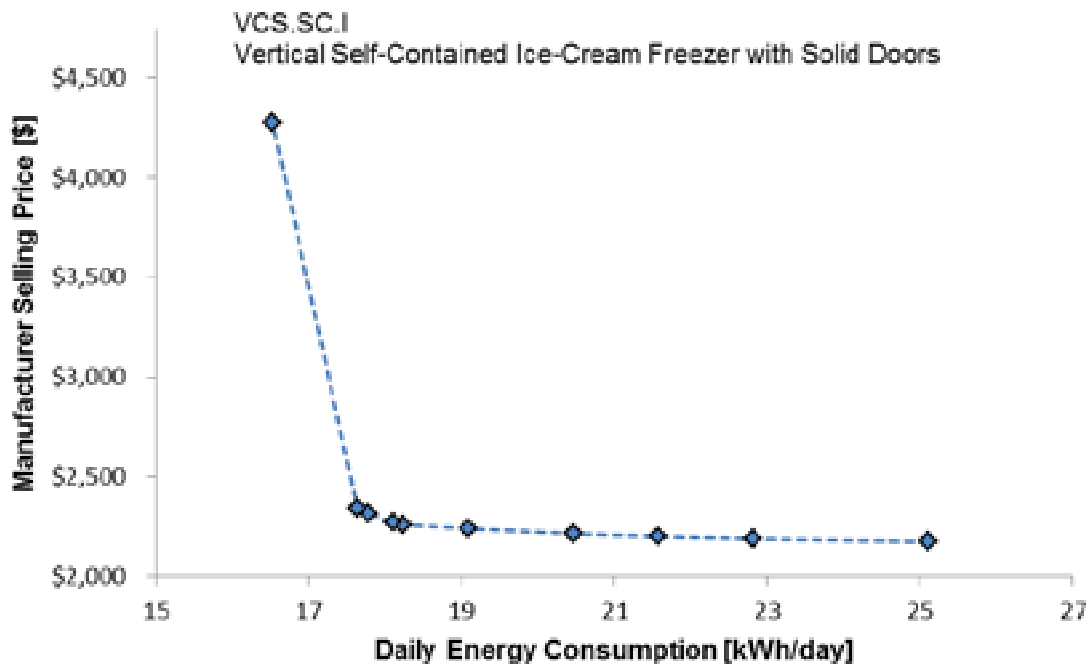

Figure 5.7.17 Cost-Efficiency Curve for the VCS.SC.I Equipment Class

Table 5.7.18 Cost-Efficiency Data for the VCS.SC.I Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	25.12	1,483.43	2,171.32	Baseline
AD2	22.82	1,495.60	2,188.60	AD1 + Enhanced-UA Condenser Coil
AD3	21.57	1,503.87	2,200.34	AD2 + Permanent Split Cap. Evap. Fan Motor
AD4	20.48	1,512.95	2,213.24	AD3 + Enhanced-UA Evaporator Coil
AD5	19.09	1,530.53	2,238.20	AD4 + Brushless DC Evap. Fan Motor
AD6	18.24	1,544.60	2,258.17	AD5 + High-Eff. Reciprocating Compressor
AD7	18.11	1,553.90	2,271.39	AD6 + Permanent Split Cap. Cond. Fan Motor
AD8	17.79	1,586.24	2,317.31	AD7 + Additional ½-inch Insulation
AD9	17.64	1,601.24	2,338.60	AD8 + Brushless DC Cond. Fan Motor
AD10	16.53	2,968.45	4,280.05	AD9 + Vacuum Insulated Panels

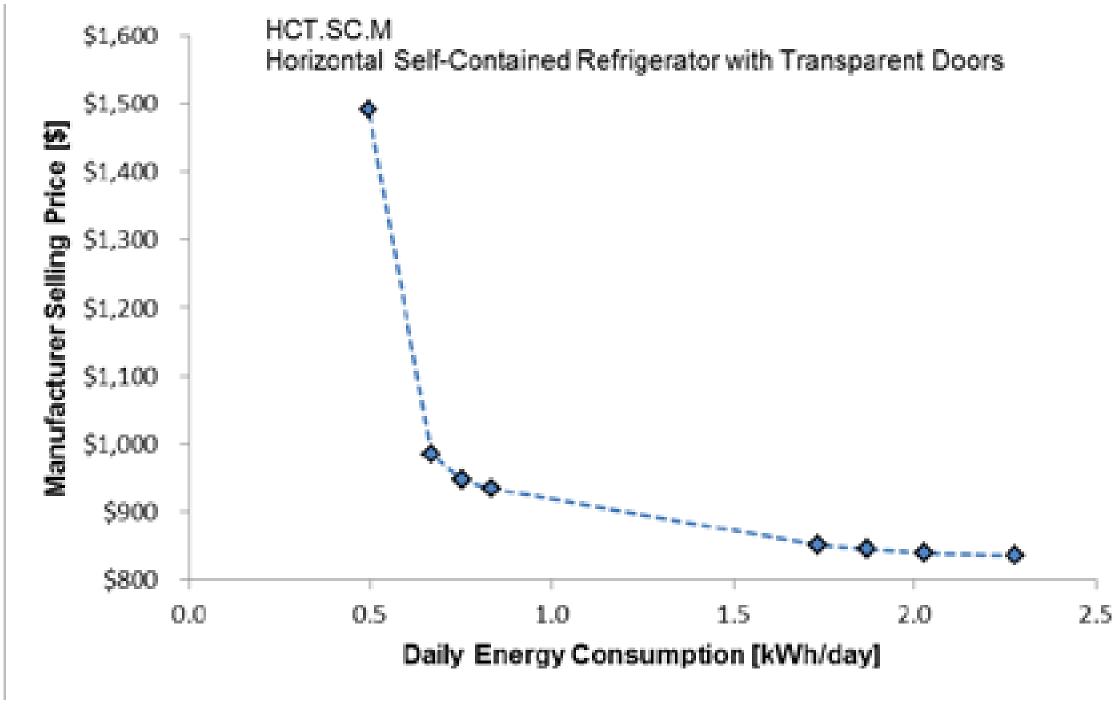

Figure 5.7.18 Cost-Efficiency Curve for the HCT.SC.M Equipment Class

Table 5.7.19 Cost-Efficiency Data for the HCT.SC.M Equipment Class

Design Option Level	**Calculated Daily Energy Consumption** ***kWh/day***	**Manufacturer Production Cost** ***$***	**Manufacturer Selling Price** ***$***	**Design Option Added Above the Baseline**
AD1	2.28	574.91	836.64	Baseline
AD2	2.03	577.51	840.33	AD1 + Enhanced-UA Condenser Coil
AD3	1.87	580.92	845.17	AD2 + High-Eff. Reciprocating Compressor
AD4	1.73	585.06	851.04	AD3 + Permanent Split Cap. Cond. Fan Motor
AD5	0.84	643.35	933.83	AD4 + High-Performance Door
AD6	0.75	652.14	946.31	AD5 + Brushless DC Cond. Fan Motor
AD7	0.67	679.02	984.47	AD6 + Additional ½-inch Insulation
AD8	0.49	1,035.59	1,490.80	AD7 + Vacuum Insulated Panels

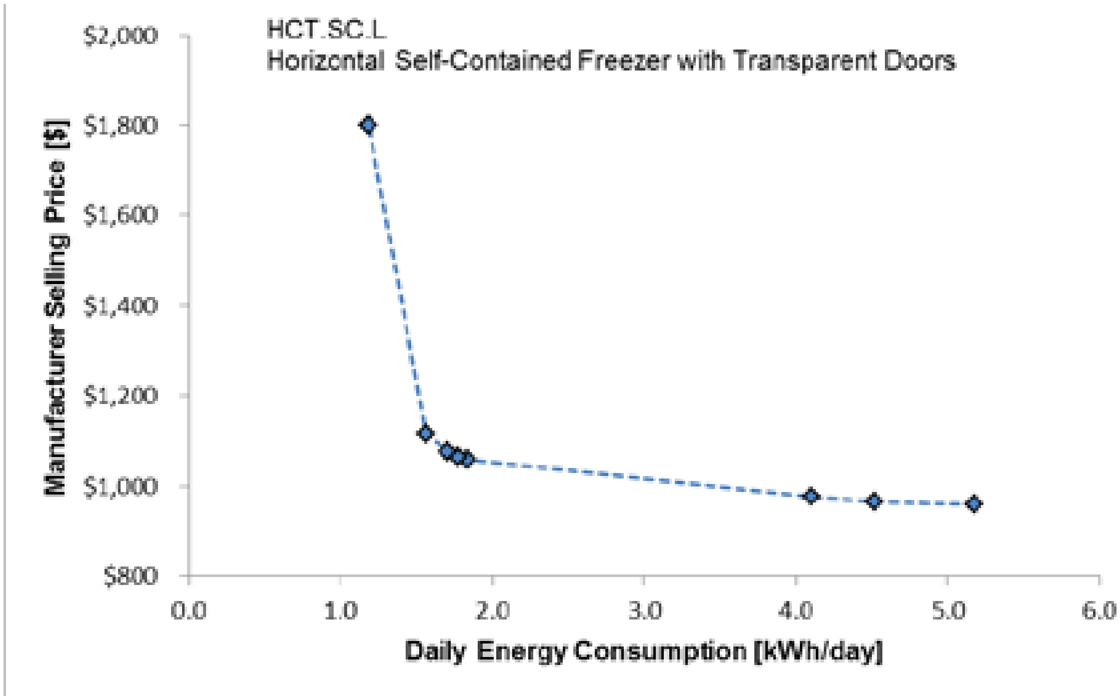

Figure 5.7.19 Cost-Efficiency Curve for the HCT.SC.L Equipment Class

Table 5.7.20 Cost-Efficiency Data for the HCT.SC.L Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	5.17	661.43	959.50	Baseline
AD2	4.52	666.13	966.17	AD1 + Enhanced-UA Condenser Coil
AD3	4.11	673.06	976.01	AD2 + High-Eff. Reciprocating Compressor
AD4	1.83	731.35	1,058.79	AD3 + High-Performance Door
AD5	1.77	735.49	1,064.66	AD4 + Permanent Split Cap. Cond. Fan Motor
AD6	1.70	744.28	1,077.14	AD5 + Brushless DC Cond. Fan Motor
AD7	1.57	771.16	1,115.31	AD6 + Additional ½-inch Insulation
AD8	1.18	1,253.50	1,800.23	AD7 + Vacuum Insulated Panels

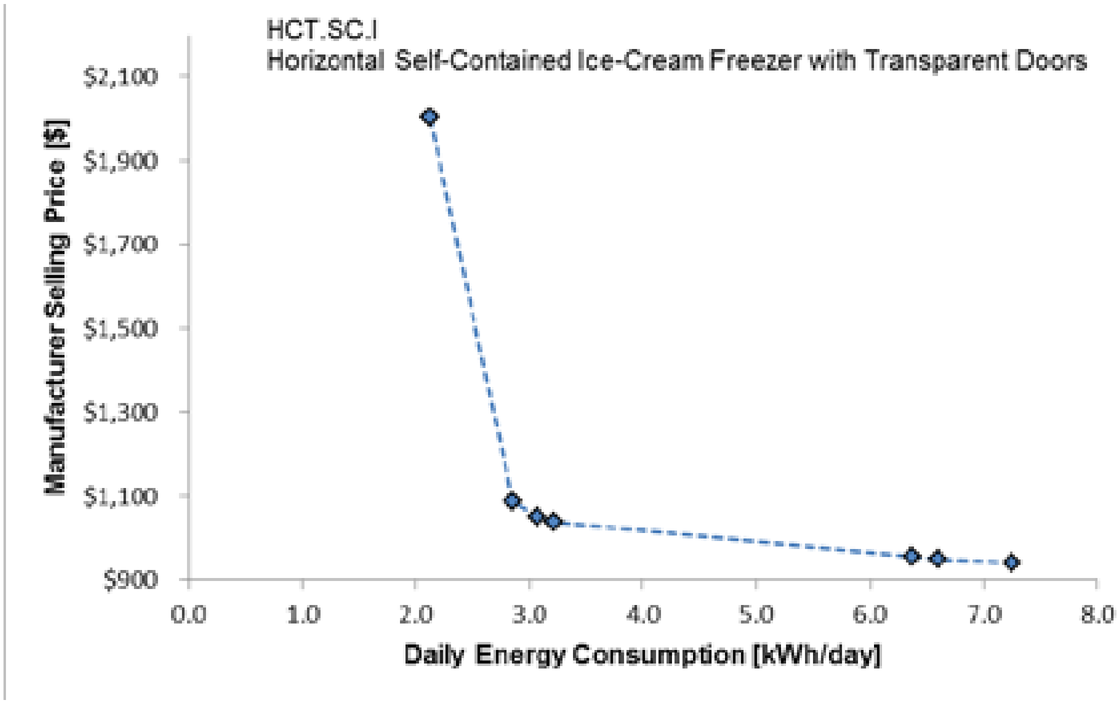

Figure 5.7.20 Cost-Efficiency Curve for the HCT.SC.I Equipment Class

Table 5.7.21 Cost-Efficiency Data for the HCT.SC.I Equipment Class

Design Option Level	**Calculated Daily Energy Consumption** *kWh/day*	**Manufacturer Production Cost** *$*	**Manufacturer Selling Price** *$*	**Design Option Added Above the Baseline**
AD1	7.25	648.75	939.46	Baseline
AD2	6.60	655.57	949.15	AD1 + High-Eff. Reciprocating Compressor
AD3	6.37	659.71	955.02	AD2 + Permanent Split Cap. Cond. Fan Motor
AD4	3.22	718.00	1,037.80	AD3 + High-Performance Door
AD5	3.07	726.79	1,050.29	AD4 + Brushless DC Cond. Fan Motor
AD6	2.86	753.93	1,088.82	AD5 + Additional 1/2" Insulation
AD7	2.13	1,398.34	2,003.87	AD6 + Vacuum Insulated Panels

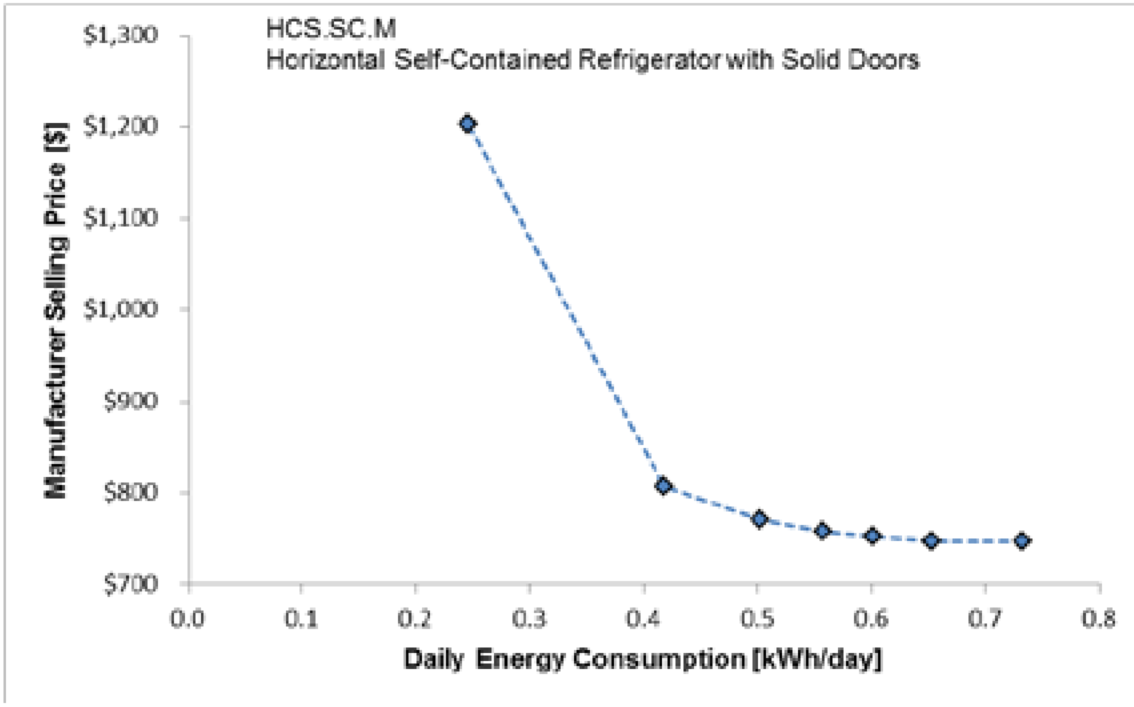

Figure 5.7.21 Cost-Efficiency Curve for the HCS.SC.M Equipment Class

Table 5.7.22 Cost-Efficiency Data for the HCS.SC.M Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	0.73	509.12	746.26	Baseline
AD2	0.65	509.96	747.45	AD1 + Enhanced-UA Condenser Coil
AD3	0.60	513.37	752.29	AD2 + High-Eff. Reciprocating Compressor
AD4	0.56	517.51	758.17	AD3 + Permanent Split Cap. Cond. Fan Motor
AD5	0.50	526.30	770.65	AD4 + Brushless DC Cond. Fan Motor
AD6	0.42	552.24	807.48	AD5 + Additional ½-inch Insulation
AD7	0.25	831.03	1,203.36	AD6 + Vacuum Insulated Panels

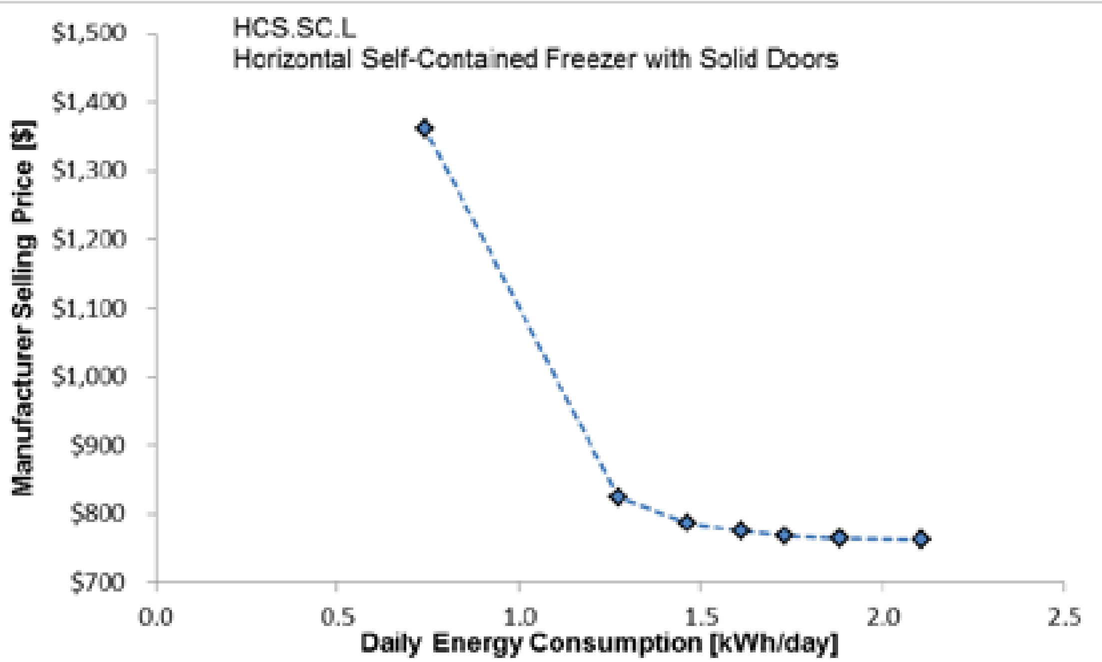

Figure 5.7.22 Cost-Efficiency Curve for the HCS.SC.L Equipment Class

Table 5.7.23 Cost-Efficiency Data for the HCS.SC.L Equipment Class

Design Option Level	**Calculated Daily Energy Consumption** ***kWh/day***	**Manufacturer Production Cost** ***$***	**Manufacturer Selling Price** ***$***	**Design Option Added Above the Baseline**
AD1	2.11	520.44	762.34	Baseline
AD2	1.88	521.70	764.12	AD1 + Enhanced-UA Condenser Coil
AD3	1.73	525.01	768.82	AD2 + High-Eff. Reciprocating Compressor
AD4	1.61	529.15	774.69	AD3 + Permanent Split Cap. Cond. Fan Motor
AD5	1.46	537.94	787.18	AD4 + Brushless DC Cond. Fan Motor
AD6	1.27	563.88	824.01	AD5 + Additional ½-inch Insulation
AD7	0.74	942.20	1,361.22	AD6 + Vacuum Insulated Panels

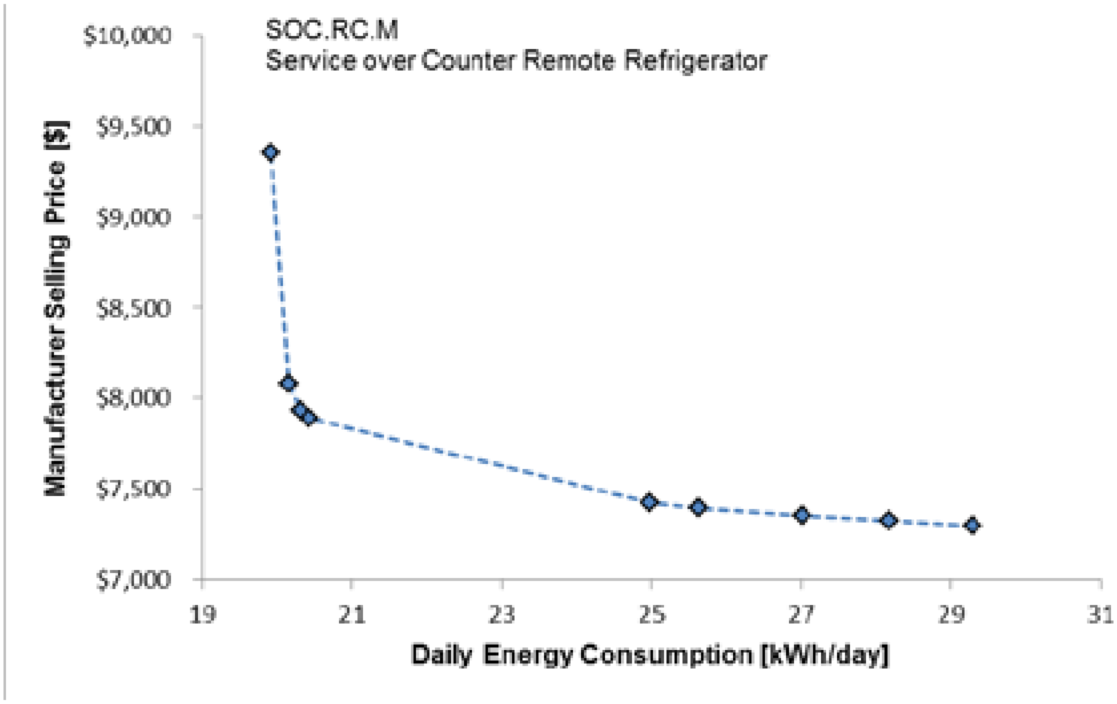

Figure 5.7.23 Cost-Efficiency Curve for the SOC.RC.M Equipment Class

Table 5.7.24 Cost-Efficiency Data for the SOC.RC.M Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	29.30	5,022.51	7,297.13	Baseline
AD2	28.18	5,041.13	7,323.56	AD1 + Permanent Split Cap. Evap. Fan Motor
AD3	27.01	5,061.81	7,352.93	AD2 + Super T8 Lighting
AD4	25.62	5,091.80	7,395.51	AD3 + Brushless DC Evap. Fan Motor
AD5	24.97	5,111.42	7,423.38	AD4 + Enhanced-UA Evaporator Coil
AD6	20.43	5,438.96	7,888.48	AD5 + LED Lighting
AD7	20.31	5,472.28	7,935.80	AD6 + Additional ½-inch Insulation
AD8	20.15	5,575.69	8,082.64	AD7 + High-Performance Door
AD9	19.93	6,467.08	9,348.41	AD8 + Vacuum Insulated Panels

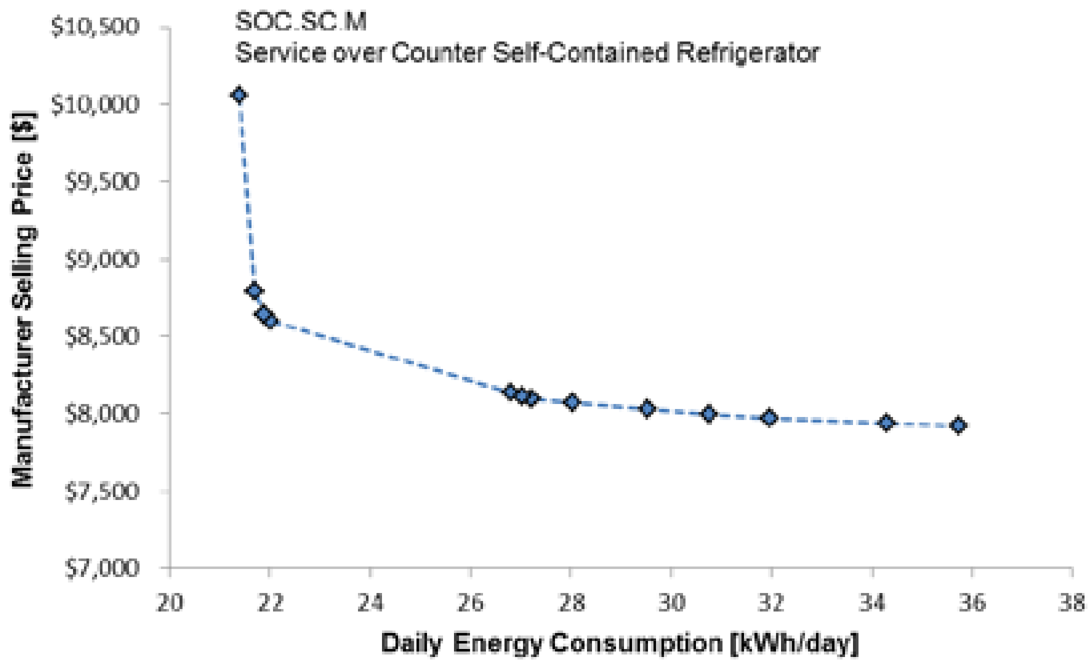

Figure 5.7.24 Cost-Efficiency Curve for the SOC.SC.M Equipment Class

Table 5.7.25 Cost-Efficiency Data for the SOC.SC.M Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	35.76	5,462.07	7,921.29	Baseline
AD2	34.32	5,471.63	7,934.88	AD1 + High-Eff. Reciprocating Compressor
AD3	31.97	5,497.92	7,972.21	AD2 + Enhanced-UA Condenser Coil
AD4	30.77	5,516.54	7,998.64	AD3 + Permanent Split Cap. Evap. Fan Motor
AD5	29.53	5,537.22	8,028.01	AD4 + Super T8 Lighting
AD6	28.04	5,567.21	8,070.59	AD5 + Brushless DC Evap. Fan Motor
AD7	27.23	5,586.83	8,098.45	AD6 + Enhanced-UA Evaporator Coil
AD8	27.04	5,596.14	8,111.67	AD7 + Permanent Split Cap. Cond. Fan Motor
AD9	26.80	5,611.13	8,132.96	AD8 + Brushless DC Cond. Fan Motor
AD10	22.02	5,938.67	8,598.07	AD9 + LED Lighting
AD11	21.88	5,971.99	8,645.38	AD10 + Additional ½-inch Insulation
AD12	21.70	6,075.40	8,792.22	AD11 + High-Performance Door
AD13	21.41	6,966.79	10,057.99	AD12 + Vacuum Insulated Panels

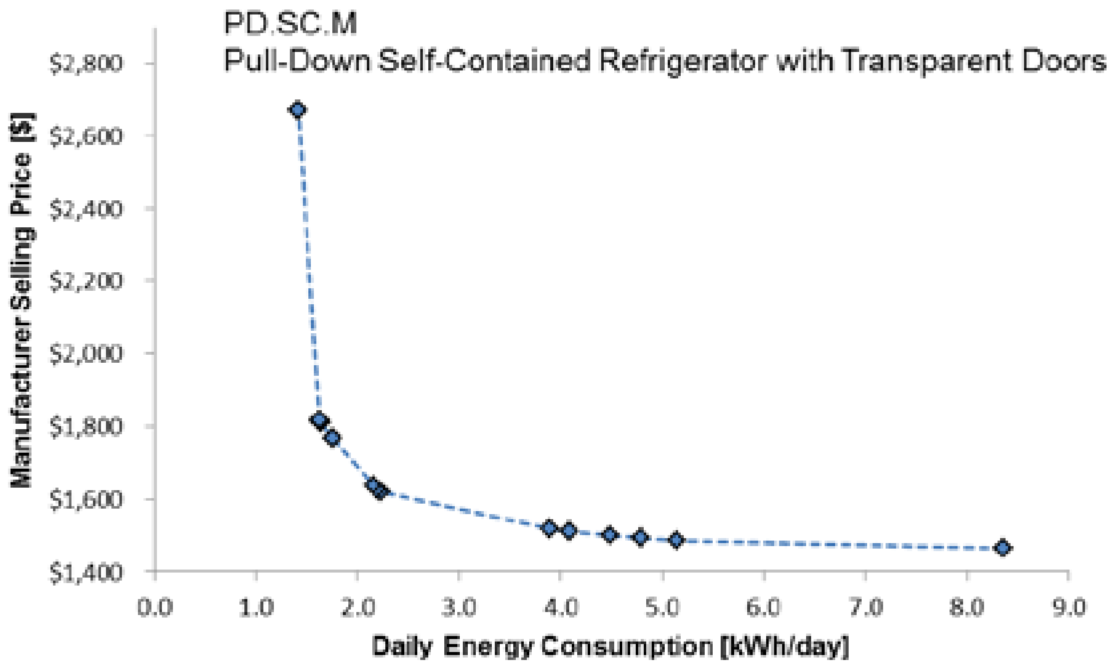

Figure 5.7.25 Cost-Efficiency Curve for the PD.SC.M Equipment Class

Table 5.7.26 Cost-Efficiency Data for the PD.SC.M Equipment Class

Design Option Level	Calculated Daily Energy Consumption *kWh/day*	Manufacturer Production Cost *$*	Manufacturer Selling Price *$*	Design Option Added Above the Baseline
AD1	8.35	1,004.47	1,463.83	Baseline
AD2	5.14	1,019.71	1,485.48	AD1 + LED Lighting
AD3	4.80	1,024.37	1,492.09	AD2 + Permanent Split Cap. Evap. Fan Motor
AD4	4.49	1,030.03	1,500.13	AD3 + Enhanced-UA Condenser Coil
AD5	4.08	1,037.52	1,510.77	AD4 + Brushless DC Evap. Fan Motor
AD6	3.90	1,043.21	1,518.85	AD5 + High-Eff. Reciprocating Compressor
AD7	2.23	1,115.38	1,621.33	AD6 + High-Performance Door
AD8	2.20	1,120.03	1,627.94	AD7 + Permanent Split Cap. Cond. Fan Motor
AD9	2.16	1,127.53	1,638.58	AD8 + Brushless DC Cond. Fan Motor
AD10	1.75	1,218.01	1,767.07	AD9 + LED Lighting with Occupancy Sensors
AD11	1.64	1,247.84	1,809.42	AD10 + Additional ½-inch Insulation
AD12	1.64	1,252.07	1,815.43	AD11 + Enhanced-UA Evaporator Coil
AD13	1.42	1,853.57	2,669.56	AD12 + Vacuum Insulated Panels

5.8 OFFSET FACTORS

Equipment energy use scales with equipment size, but smaller equipment tends to use more energy per unit of TDA or volume than larger equipment in the same equipment class. This extra energy is attributed to components of case load that do not scale with equipment size.

These load components therefore have a disproportionate effect on the energy consumption of small equipment. In its 2009 final rule, DOE developed offset factors to account for these load components, commonly referred to as "end effects," as a way to adjust standards to allow more energy use for smaller equipment.

During the early stages of the 2009 final rule analysis, stakeholders raised concerns that standards developed for large sizes of equipment would be unfair when applied to smaller equipment in the same class, because of the end effects that disproportionately affect smaller equipment. In its engineering analysis, DOE developed cost-efficiency curves for a single size within each equipment class. The representative size selected for each class was toward the larger end of the equipment available within that class. DOE intended for standards to be based on this single analysis point (the point defined by TDA or volume and CDEC). Accordingly, in the 2009 rulemaking advance notice of proposed rulemaking, DOE expressed intent to implement standards by requiring equipment to meet an energy consumption limit defined by a line drawn between the origin and the point determined by the engineering cost-efficiency curve. (See the left pane of Figure 5.8.1.) However, the stakeholder concerns previously mentioned led DOE to account for end effects in later stages of the rulemaking and in the final rule. As the right pane of Figure 5.8.1 shows, the offset factor fixes the left end of the standard equation at a fixed offset on the CDEC axis, effectively providing a higher limit on energy consumption for smaller equipment.

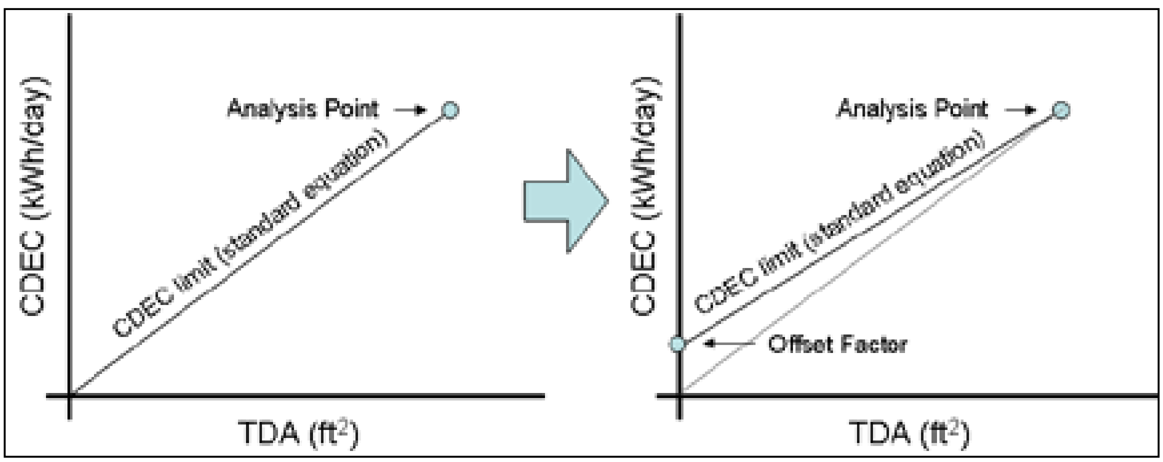

Figure 5.8.1 Illustration of Offset Factor using TDA as the Normalization Metric

Using this methodology, a standard equation consists of two components: a size-dependent multiplier (slope) and a constant (offset factor). DOE calculated the slopes of the standard equations for its 2009 final rule standard levels as the difference between the CDEC at the analysis point corresponding to the selected standard level and the offset factor, divided by the value of the normalization metric at the analysis point.

In determining offset factors in the 2009 final rule, DOE considered different end effects for each equipment family. For all open cases (VOP, SVO, and HZO), DOE considered the effects of heat conduction through the case ends, as well as the infiltration load end effects. For VCT cases, the conduction through the ends was taken into account, as well as the heat load and electrical load of one T8 lamp. In the remaining equipment families (SOC, HCT, VCS), DOE only considered the conduction effects through the case ends. DOE then summed these heat loads for each class and calculated the daily energy use of the compressor for that class. For all equipment classes except for those in the VCT equipment family, this became the offset factor. For VCT equipment, DOE also considered the amount of electrical energy consumed by lighting. These values then become the offset factors, representing energy use end effects for each equipment class in the 2009 final rule standard-level equations. Similarly, the EPACT 2005 standard-level equations also contained analogous values that would provide a non-zero energy allowance at zero volume, representing the end effects for that equipment.

When developing standard-level equations for each primary equipment class at the five trial standard levels (TSLs) considered in this NOPR, DOE revised the offset factors in the current standard levels commensurately to reflect decreasing energy use by a given unit at higher TSLs. However, adjusting the offset factors and the analysis point (the energy consumption of the representative unit modeled in the engineering analysis) disproportionately in comparison to the values allowed by the current standards would cause a significant change in the slopes of the standard-level equations, resulting in standard levels that would negatively impact either smaller or larger units as compared to the existing EPACT 2005 and 2009 final rule standards. To avoid this, DOE instead scaled the existing offset factors from the 2009 final rule and EPACT 2005 standards using the engineering analysis results for each equipment class at each TSL. DOE first calculated the allowable energy consumption under the existing standard for each class at the representative size analyzed, and then compared those standards values to the energy consumption values at each TSL produced by the engineering analysis. The ratio of these two values was then used as a multiplier on the existing offset factor for each equipment class at each TSL, and the resulting values were used as the offset factors for the new standard-level equations.

5.9 EXTENSION OF ANALYSIS TO SECONDARY EQUIPMENT CLASSES

In its 2009 final rule, DOE did not analyze all covered equipment classes, but focused its analysis on 15 high-shipment equipment classes. In that rule, DOE developed an extension approach to apply the standards developed for these 15 “primary” classes to the remaining 23 “secondary” classes. This approach involved extension multipliers developed with the 15 primary results and a set of focused matched-pair analyses. The matched-pair analyses compared calculated energy consumption levels for pieces of equipment with similar designs but one major construction or operational difference corresponding to a change in the equipment family, condenser configuration, or operating temperature. For example, vertical open remote condensing cases operating at medium and low temperatures were compared in one portion of the analysis. The relationships between these sets of units were then used to determine the isolated effect of the given design or operational difference on applicable equipment. These extension multipliers represent the relationship in terms of energy consumption between different equipment classes, such as remote condensing and self-contained equipment with a given operating temperature and door configuration. In addition, DOE determined that standards for certain primary equipment classes could be directly applied to other similar secondary equipment classes, implying that the extension multiplier is equal to 1.0. Section 5.9.1 describes in detail the methodology that DOE used in the 2009 final rule analyses to develop extension multipliers.

After examining the performance and characteristics of the equipment classes analyzed in the current rulemaking, DOE preserved the 2009 extension multiplier approach for application in this rulemaking. DOE's use of this approach in the current rulemaking is discussed in detail in section 5.9.2.

5.9.1 Development of Extension Multiplier Approach in 2009 Rulemaking

During the 2009 rulemaking, DOE examined extending standards using the 15 primary equipment classes developed in its engineering analysis. Using size-normalized baseline energy consumption values, several trends became apparent for certain subgroups of equipment. DOE examined several related pairs of equipment classes to develop extension multipliers.

First, DOE examined the energy consumption/TDA relationship between remote and self-contained medium-temperature equipment without doors (Table 5.9.1). There was reasonable agreement across equipment families among medium-temperature open equipment, with an average multiplier of 2.51 between remote and self-contained equipment. The differences between remote and self-contained equipment were similar for VOP, SVO, and HZO equipment. In addition to the inclusion of a self-contained condensing unit, which is less efficient than remote condensing systems, self-contained open equipment must have provisions for dealing with defrost meltwater. Because self-contained equipment is designed to be mobile, defrost meltwater must be collected in a drain pan and evaporated using electric-resistance heating. This feature adds considerable energy use to open self-contained equipment, helping to explain the larger energy consumption of self-contained equipment. The 2.51 multiplier was also applicable to low- and ice-cream-temperature equipment without doors. The differences in design were found to be similar for low-temperature and ice-cream-temperature equipment, consisting of a self-contained condensing unit and the addition of a defrost meltwater evaporation system. Thus, the 2.51 multiplier was applied to the following standard extensions in the 2009 final rule:

- VOP.RC.L to VOP.SC.L
- SVO.RC.L to SVO.SC.L
- VOP.RC.I to VOP.SC.I
- SVO.RC.I to SVO.SC.I
- HZO.RC.I to HZO.SC.I

Table 5.9.1 Extension Multipliers for Remote and Self-Contained Equipment Without Doors

Relationship	CDEC/TDA Multiplier
VOP.RC.M to VOP.SC.M	2.431
SVO.RC.M to SVO.SC.M	2.376
HZO.RC.M to HZO.SC.M	2.712

DOE next examined the CDEC/TDA relationship between low-temperature and ice-cream-temperature remote equipment using a focused matched-pair analysis. The focused matched-pair analysis methodology established a correlation between rating temperature levels and CDEC/TDA, using data collected from manufacturer specification sheets. DOE quantified the differences in energy consumption for matched pairs of equipment classes that were very similar in features and dimensions but had different operating temperatures. Pairs of units at low and ice-cream temperatures were selected from several different manufacturers for comparison. From a given manufacturer DOE selected identical units designed to operate at multiple temperatures to isolate operating temperature as the only variable.

The matched-pair results showed that VCT.RC.I units (at -15 °F) had on average CDEC/TDA values that were 1.17 times higher than comparable VCT.RC.L units. The 1.17 multiplier was also applicable to other similar equipment types with doors. Differences in design consisted of a lower operating temperature (resulting in a lower compressor EER) and higher defrost and anti-sweat heater power. Thus, the 1.17 multiplier was applied to the following standard extensions:

- SOC.RC.L to SOC.RC.I
- HCT.RC.L to HCT.RC.I

The matched-pair results further showed that HZO.RC.I units (at -15 °F) had on average CDEC/TDA values that were 1.27 times higher than comparable HZO.RC.L units. The 1.27 multiplier was also applicable to other similar equipment types without doors. Differences in design consisted of a lower operating temperature (resulting in a lower compressor EER) and higher defrost and anti-sweat heater power. Thus, the 1.27 multiplier was applied to the following standard extensions:

- VOP.RC.L to VOP.RC.I
- SVO.RC.L to SVO.RC.I
- VOP.SC.L to VOP.SC.I
- SVO.SC.L to SVO.SC.I
- HZO.SC.L to HZO.SC.I

DOE next examined the CDEC/TDA relationship between remote and self-contained ice-cream-temperature equipment with transparent doors. To make this comparison, DOE used the matched-pair results to estimate the baseline CDEC/TDA values for VCT.RC.I equipment, and compared the results to VCT.SC.I equipment. The comparison showed that CDEC/TDA values for VCT.SC.I equipment were 1.40 times higher than VCT.RC.I equipment. DOE understood that this difference in energy use was due to the differences in efficiency of the self-contained condensing unit, as well as the addition of defrost meltwater evaporation systems. However, in contrast to open equipment, equipment with transparent doors is subject to a much lower infiltration load, and thus a lower meltwater evaporation requirement. This led to a lower multiplier than was seen for open equipment. The 1.40 multiplier was applied to the following standard extensions:

- SOC.RC.I to SOC.SC.I
- HCT.RC.I to HCT.SC.I
- VCS.RC.I to VCS.SC.I
- HCS.RC.I to HCS.SC.I

Finally, DOE examined the relationship between medium- and low-temperature remote equipment with transparent doors. Both the VCT.RC.M and VCT.RC.L equipment classes were directly examined in the engineering analysis. Using the engineering results, the comparison showed that CDEC/TDA values for VCT.RC.L equipment were 2.10 times higher than VCT.RC.M equipment. This difference was due to the higher defrost heater power and anti-sweat heater power requirements of low-temperature equipment. The 2.10 multiplier was applied to the standard extension from HCT.RC.M to HCT.RC.L in the 2009 final rule.

5.9.2 Current Use of Extension Multiplier Methodology

In the current rulemaking, DOE preserved the extension multiplier approach and values used in the 2009 final rule analysis (and described in section 5.9.1) for the classes covered under that rulemaking. As the standards set in the 2009 final rule carried a compliance date of January 1, 2012, DOE was not able to analyze equipment manufactured to comply with those standards as part of its engineering analysis for the current rulemaking. Therefore DOE used, as discussed previously, a market baseline of available equipment specifications, which was the same as that used in the 2009 final rule. Because the extension multipliers were developed in the 2009 final rule based on normalized baseline energy consumption values, and the engineering baseline was not changed in this rulemaking, DOE believes that the multipliers from the 2009 rulemaking continue to accurately represent the relationship of the respective various equipment groups, and can be retained. Additionally, because these multipliers largely reflect the existence of basic differences in design features and thermal performance between classes, which will always exist regardless of efficiency improvement with the classes, DOE believes that these multipliers remain applicable to the equipment designs covered in the current rulemaking.

DOE used these extension multipliers by applying them alone or in combination to the standard-level equations, based on the results of the engineering analysis and the offset factors calculated, that it had developed for the primary equipment classes at the baseline and each of the five TSLs. The result was a set of standard-level equations for all of the secondary equipment classes at the TSLs examined. The values of the extension multipliers used and the equipment type relationships to which they correspond are listed in Table 5.9.2.

Table 5.9.2 Extension Multipliers

Extension Multiplier Value	Extension Relationship
2.51	Medium temperature to low temperature; equipment without doors; Example, VOP.SC.M to VOP.SC.L
1.17	Low temperature to ice-cream temperature for equipment with transparent doors; Example, VCT.RC.L to VCT.RC.I
1.27	Low temperature to ice-cream temperature for equipment without doors; Example VOP.RC.L to VOP.RC.I
1.40	Remote condensing to self-contained for equipment with doors; Example VCS.RC.I to VCS.SC.I
2.10	Medium temperature to low temperature for equipment with doors; Example SOC.RC.M to SOC.RC.L

These five extension multipliers were sufficient to extend standard-level equations from the primary equipment classes to all 24 secondary equipment classes. The specific extension multiplier combinations used to yield standard-level equations at each TSL for the secondary classes are depicted in Table 5.9.3.

Table 5.9.3 Extension Multipliers by Equipment Class

		RC			**SC**		
		I	**L**	**M**	**I**	**L**	**M**
Open	**VOP**	1.27a	**a***	**b**	1.27(2.51c)	2.51c	c
	SVO	1.27a	a**	**d**	1.27(2.51e)	2.51e	e
	HZO	1.27f	**f**	**g**	1.27h	h	i
Closed	**SOC**	1.17(2.10j)	2.10j	**j**	1.40(1.17(2.10j))	2.10p	p
	VCT	1.17k	**k**	**l**	**m**	EPACT 2005 Primary Classes[†]	
	HCT	n/1.40	(n/1.40)/1.17	((n/1.40)/1.17)/2.10	**n**		
	VCS	o/1.40	(o/1.40)/1.17	((o/1.40)/1.17)/2.10	**o**		
	HCS	o/1.40	(o/1.40)/1.17	((o/1.40)/1.17)/2.10	o**		

*Classes represented by bold letters are primary classes examined directly in the engineering analysis

**The SVO.RC.L and HCS.SC.I classes were determined to have the exact same normalized baseline energy consumption levels as the VOP.RC.L and VCS.SC.I classes, respectively.

†Equipment classes for which standards were set in EPACT 2005 are all primary classes except for SOC.SC.L. Thus no extension multipliers were needed or relevant in developing proposed standards for these classes of EPACT 2005 equipment.

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APPENDIX 5A. ENGINEERING DATA

5A.1 INTRODUCTION

This appendix presents baseline specifications and other details for each of the commercial refrigeration equipment classes directly analyzed in the engineering analysis (chapter 5 of the technical support document (TSD)).

5A.2 BASELINE SPECIFICATIONS

Table 5A.2.1 shows baseline design options for each of the commercial refrigeration equipment classes analyzed in the engineering analysis. All changes to cost and efficiency are measured relative to this level in the engineering analysis. Refer to chapter 5 of the TSD for details about each baseline technology.

Table 5A.2.2 shows baseline specifications (or case design specifications) for each of the commercial refrigeration equipment classes analyzed in the engineering analysis. These specifications include dimensions, numbers of components, temperatures, nominal power ratings, and other case features that are necessary to calculate the energy consumption of each equipment class. In conjunction with baseline design option levels, the baseline specifications define the energy consumption and cost of the typical minimum technology equipment on the market.

Table 5A.2.1 Baseline Design Options[a]

	VOP.RC.M	VOP.RC.L	VOP.SC.M	SVO.RC.M	SVO.SC.M	HZO.RC.M	HZO.RC.L	HZO.SC.M
Lighting for VOP, SVO, and SOC	T8 Electronic	T8 Electronic	T8 Electronic	T8 Electronic	T8 Electronic	-	-	-
Lighting for VCT and PD	-	-	-	-	-	-	-	-
Evaporator Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil	Standard Coil
Evaporator Fan Motors	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole
Case Insulation	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard
Doors for VCT.XX.L/I	-	-	-	-	-	-	-	-
Doors for VCT/PD.XX.M	-	-	-	-	-	-	-	-
Doors for HCT.XX.L/I	-	-	-	-	-	-	-	-
Doors for HCT.XX.M	-	-	-	-	-	-	-	-
Doors for SOC.XX.L/I	-	-	-	-	-	-	-	-
Doors for SOC.XX.M	-	-	-	-	-	-	-	-
Condenser Coil Area (SC Only)	-	-	Standard	-	Standard	-	-	Standard
Condenser Fan Motors (SC only)	-	-	Shaded Pole	-	Shaded Pole	-	-	Shaded Pole
Compressor (SC only)	-	-	Single-Speed Hermetic	-	Single-Speed Hermetic	-	-	Single-Speed Hermetic
Night Curtains	None	None	None	None	None	-	-	-

[a] Equipment class designations consist of a combination—in sequential order separated by a period—of an equipment family code (VOP - vertical open, SVO - semivertical open, HZO - horizontal open, VCT - vertical closed transparent, VCS - vertical closed solid, HCT - horizontal closed transparent, HCS - horizontal closed solid, SOC - service over counter, or PD – pull-down equipment), an operating mode code (RC - remote condensing or SC - self-contained), and a rating temperature code (M - medium temperature, L - low temperature, or I - ice-cream temperature). See chapter 3, Market and Technology Assessment, for a more detailed explanation of the equipment class terminology.

Table 5A.2.1 (cont)

	HZO.SC.L	VCT.RC.M	VCT.RC.L	VCT.SC.M	VCT.SC.L	VCT.SC.I	VCS.SC.M	VCS.SC.L	VCS.SC.I
Lighting for VOP, SVO, and SOC	-	-	-	-	-	-	-	-	-
Lighting for VCT and PD	-	T8 Electronic	T8 Electronic	T8 Electronic	T8 Electronic	T8 Electronic	-	-	-
Evaporator Coil	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard
Evaporator Fan Motors	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole
Case Insulation	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard
Doors for VCT.XX.L/I	-	-	Standard	-	Standard	Standard	-	-	-
Doors for VCT/PD.XX.M	-	Standard	-	Standard	-	-	-	-	-
Doors for HCT.XX.L/I	-	-	-	-	-	-	-	-	-
Doors for HCT.XX.M	-	-	-	-	-	-	-	-	-
Doors for SOC.XX.L/I	-	-	-	-	-	-	-	-	-
Doors for SOC.XX.M	-	-	-	-	-	-	-	-	-
Condenser Coil Area (SC Only)	Standard	-	-	Standard	Standard	Standard	Standard	Standard	Standard
Condenser Fan Motors (SC only)	Shaded Pole	-	-	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole
Compressor (SC only)	Single-Speed Hermetic	-	-	Single-Speed Hermetic	Single-Speed Hermetic	Single-Speed Hermetic	Single-Speed Hermetic	Single-Speed Hermetic	Single-Speed Hermetic
Night Curtains	-	-	-	-	-	-	-	-	-

Table 5A.2.1 (cont)

	HCT.SC.M	HCT.SC.L	HCT.SC.I	HCS.SC.M	HCS.SC.L	SOC.SC.M	SOC.RC.M	PD.SC.M
Lighting for VOP, SVO, and SOC	-	-	-	-	-	T8 Electronic	T8 Electronic	-
Lighting for VCT and PD	-	-	-	-	-	-	-	T8 Electronic
Evaporator Coil	-	-	-	-	-	Standard	Standard	Standard
Evaporator Fan Motors	-	-	-	-	-	Shaded Pole	Shaded Pole	Shaded Pole
Case Insulation	Standard	Standard	Standard	Standard	Standard	Standard	Standard	Standard
Doors for VCT.XX.L/I	-	-	-	-	-	-	-	-
Doors for VCT/PD.XX.M	-	-	-	-	-	-	-	Standard
Doors for HCT.XX.L/I	-	Standard	Standard	-	-	-	-	-
Doors for HCT.XX.M	Standard	-	-	-	-	-	-	-
Doors for SOC.XX.L/I	-	-	-	-	-	-	-	-
Doors for SOC.XX.M	-	-	-	-	-	Standard	Standard	-
Condenser Coil Area (SC Only)	Standard	Standard	Standard	Standard	Standard	Standard	-	Standard
Condenser Fan Motors (SC only)	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	Shaded Pole	-	Shaded Pole
Compressor (SC only)	Single-Speed Hermetic	Single-Speed Hermetic	Single-Speed Hermetic	Single-Speed Hermetic	Single-Speed Hermetic	Single-Speed Hermetic	-	Single-Speed Hermetic
Night Curtains	-	-	-	-	-	-	-	-

Table 5A.2.2 Baseline Specifications

	VOP.RC.M	VOP.RC.L	VOP.SC.M	SVO.RC.M	SVO.SC.M	HZO.RC.M	HZO.RC.L
Case Length (ft)	12	12	4	12	4	12	12
Case Gross Refrigerated Volume (ft^3)	130.2	109.83	32	46.55	9.4	33	55
Case Total Display Area (ft^2)	53.3	44.66	14.93	40	12.8	33	46
Number of Doors (#)	0	0	0	0	0	0	0
Single Door Area (ft^2)	0	0	0	0	0	0	0
Non-Door Glass Area (ft^2)	0	0	0	0	0	0	0
Non-Door Anti-Sweat Power (W)	0	600	0	50	100	50	200
Wall Area (ft^2)	175.925	214	61	113.4	40.2	93.275	140
Insulation Thickness (in.)	1.5	2	1.5	1.5	1.5	1.5	2
Case Interior Surface Area (ft^2)	130.225	118.5	47.5	72.5	21.3	48.35	82
Air Curtain Angle from Vertical (°)	8.5	7.28	6.05	47	57	82	90
Infiltrated Air Mass Flow (lb/hr)	860	530	300	590	220	250	140
Number of Bulbs in Conditioned Space (#)	12	0	4	9	3	0	0
Number of Bulbs Not in Conditioned Space (#)	9	9	3	6	2	0	0
Number of Ballasts in Conditioned Space (#)	0	0	0	0	0	0	0
Number of Ballasts Not in Conditioned Space (#)	7	3	3	5	2	0	0
Evaporator Fan Nominal Rated Wattage (W/fan)	9	9	6	9	6	9	9
Number of Evaporator Fans per Case (#)	6	14	2	4	1	4	4
Condenser Fan Nominal Rated Wattage (W/fan)	0	0	9	0	9	0	0
Number of Condenser Fans per Case (#)	0	0	3	0	2	0	0
Discharge Air Temperature (DAT) (F)	25	-10	25	25	25	25	-10
Baseline Evaporator Temperature (SET) (F)	15	-20	15	15	15	15	-20
Baseline Condenser Temperature (SCT) (F)	0	0	95	0	95	0	0
Compressor Oversize Multiplier	0	0	1.3	0	1.3	0	0
Defrost Mechanism (OFF, ELE, MAN)	OFF	ELE	OFF	OFF	OFF	ELE	ELE
Defrost Time per Day (hr)	4.5	2	2.8	3	2.8	1	1
Defrost and Drain Heater Power (W)	0	8700	0	0	0	1000	3000
Condensate Pan Heater Power (W)	0	0	1500	0	1100	0	0

Table 5A.2.2 (cont)

	HZO.SC.M	HZO.SC.L	VCT.RC.M	VCT.RC.L	VCT.SC.M	VCT.SC.L	VCT.SC.I
Case Length (ft)	4	4	12.725	12.74	4.5	4.5	4.3
Case Gross Refrigerated Volume (ft^3)	7.5	7.4	142	133.5	49	49	48
Case Total Display Area (ft^2)	12	12	65	65	20.7	20.7	26
Number of Doors (#)	0	0	5	5	2	2	2
Single Door Area (ft^2)	0	0	13	13	10.35	10.35	13
Non-Door Glass Area (ft^2)	4	4	0	0	0	0	0
Non-Door Anti-Sweat Power (W)	100	300	0	0	0	0	0
Wall Area (ft^2)	54	52	204	200	73.02	73.02	77
Insulation Thickness (in.)	1.5	2	1.5	2	1.5	2	2.5
Case Interior Surface Area (ft^2)	19.8	19.5	146.5	145	63.98	63.98	64
Air Curtain Angle from Vertical (°)	85	85	-	-	-	-	-
Infiltrated Air Mass Flow (lb/hr)	100	100	30	30	10.61	10.60	15
Number of Bulbs in Conditioned Space (#)	0	0	6	6	3	3	3
Number of Bulbs Not in Conditioned Space (#)	0	0	0	0	0	0	0
Number of Ballasts in Conditioned Space (#)	0	0	6	6	3	3	3
Number of Ballasts Not in Conditioned Space (#)	0	0	0	0	0	0	0
Evaporator Fan Nominal Rated Wattage (W/fan)	6	9	6	9	6	9	9
Number of Evaporator Fans per Case (#)	1	1	5	5	2	2	2
Condenser Fan Nominal Rated Wattage (W/fan)	6	6	0	0	6	6	6
Number of Condenser Fans per Case (#)	1	1	0	0	2	2	2
Discharge Air Temperature (DAT) (F)	25	-10	32	-5	32	-5	-20
Baseline Evaporator Temperature (SET) (F)	15	-20	27	-11	27	-11	-30
Baseline Condenser Temperature (SCT) (F)	95	95	0	0	95	95	95
Compressor Oversize Multiplier	1.3	1.3	0	0	1.3	1.3	1.3
Defrost Mechanism (OFF, ELE, MAN)	ELE	ELE	OFF	ELE	OFF	ELE	ELE
Defrost Time per Day (hr)	1	1.5	1	1	1	1	1
Defrost and Drain Heater Power (W)	400	900	0	5000	0	1766.09	2580
Condensate Pan Heater Power (W)	300	400	0	0	0	200	200

Table 5A.2.2 (cont)

	VCS.SC.M	VCS.SC.L	VCS.SC.I	HCT.SC.M	HCT.SC.L	HCT.SC.I	HCS.SC.M
Case Length (ft)	4.5	4.5	4.3	3.8	3.8	3.42	4.2
Case Gross Refrigerated Volume (ft^3)	49	49	48	8.83	8.83	10.2	7.03
Case Total Display Area (ft^2)	0	0	0	7.656	7.656	5.12	0
Number of Doors (#)	2	2	2	2	2	2	1
Single Door Area (ft^2)	10.35	10.35	13	3.828	3.828	2.56	7.03
Non-Door Glass Area (ft^2)	0	0	0	0	0	0	0
Non-Door Anti-Sweat Power (W)	0	0	250	0	0	0	0
Wall Area (ft^2)	73.02	73.02	77	34.75	34.75	36.77	27.50
Insulation Thickness (in.)	1.5	2	2.5	1.5	2	2.5	1.5
Case Interior Surface Area (ft^2)	0	0	0	0	21.34	26.1	0
Air Curtain Angle from Vertical (°)	-	-	-	-	-	-	-
Infiltrated Air Mass Flow (lb/hr)	10.61	10.60	15	2.25	2.25	3	2.49
Number of Bulbs in Conditioned Space (#)	0	0	0	0	0	0	0
Number of Bulbs Not in Conditioned Space (#)	0	0	0	0	0	0	0
Number of Ballasts in Conditioned Space (#)	0	0	0	0	0	0	0
Number of Ballasts Not in Conditioned Space (#)	0	0	0	0	0	0	0
Evaporator Fan Nominal Rated Wattage (W/fan)	6	9	9	0	0	0	0
Number of Evaporator Fans per Case (#)	2	2	2	0	0	0	0
Condenser Fan Nominal Rated Wattage (W/fan)	6	6	6	9	9	9	9
Number of Condenser Fans per Case (#)	2	2	2	1	1	1	1
Discharge Air Temperature (DAT) (F)	32	-5	-20	32	-5	-20	32
Baseline Evaporator Temperature (SET) (F)	27	-11	-30	27	-11	-30	27
Baseline Condenser Temperature (SCT) (F)	95	95	95	95	95	95	95
Compressor Oversize Multiplier	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Defrost Mechanism (OFF, ELE, MAN)	OFF	ELE	ELE	OFF	MAN	MAN	OFF
Defrost Time per Day (hr)	1	1	1	1	0	0	1
Defrost and Drain Heater Power (W)	0	1766.09	2580	0	0	0	0
Condensate Pan Heater Power (W)	0	200	200	0	0	0	0

Table 5A.2.2 (cont)

	HCS.SC.L	SOC.SC.M	SOC.RC.M	PD.SC.M
Case Length (ft)	4.2	12	12	2.5
Case Gross Refrigerated Volume (ft^3)	7.03	66	66	27
Case Total Display Area (ft^2)	0	51	51	11.6
Number of Doors (#)	2	6	6	1
Single Door Area (ft^2)	3.125	3.5	3.5	11.6
Non-Door Glass Area (ft^2)	0	30	30	0
Non-Door Anti-Sweat Power (W)	0	200	200	0
Wall Area (ft^2)	27.5	84.6	84.6	57.58
Insulation Thickness (in.)	2	1.5	1.5	1.5
Case Interior Surface Area (ft^2)	0	61.6	61.6	46.71
Air Curtain Angle from Vertical (°)	-	-	-	-
Infiltrated Air Mass Flow (lb/hr)	2.49	15	15	5.89
Number of Bulbs in Conditioned Space (#)	0	15	15	2
Number of Bulbs Not in Conditioned Space (#)	0	0	0	0
Number of Ballasts in Conditioned Space (#)	0	0	0	1
Number of Ballasts Not in Conditioned Space (#)	0	5	5	0
Evaporator Fan Nominal Rated Wattage (W/fan)	0	6	6	6
Number of Evaporator Fans per Case (#)	0	4	4	1
Condenser Fan Nominal Rated Wattage (W/fan)	9	6	0	6
Number of Condenser Fans per Case (#)	1	2	0	1
Discharge Air Temperature (DAT) (F)	-5	30	30	32
Baseline Evaporator Temperature (SET) (F)	-11	20	20	27
Baseline Condenser Temperature (SCT) (F)	95	95	0	95
Compressor Oversize Multiplier	1.3	1.3	0	2
Defrost Mechanism (OFF, ELE, MAN)	MAN	ELE	ELE	OFF
Defrost Time per Day (hr)	0	1.2	1.2	1
Defrost and Drain Heater Power (W)	0	1600	1600	0
Condensate Pan Heater Power (W)	0	0	0	0

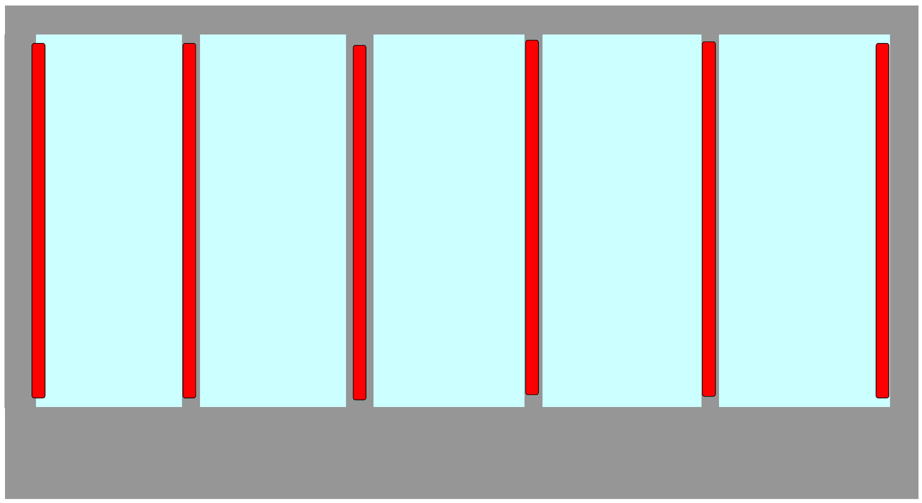
5A.3 LIGHTING CONFIGURATIONS

Lighting for use in cases with transparent doors functions differently than lighting for use in cases without doors. Cases with transparent doors typically display boxed merchandise, and only products on the front of the shelves are visible to the consumer. Therefore, the only portion of the display case that requires illumination is the area on the front surface of the case at the front of the shelves. Since this is only a limited area that requires lighting, light-emitting diodes (LEDs) offer an advantage over fluorescent lighting in vertical refrigerated cases with transparent doors because of the directional nature of LED lighting.

As part of the engineering analysis for the 2009 final rule (74 FR 1092 (Jan. 9, 2009)), the U.S. Department of Energy (DOE), with input from manufacturers and other stakeholders, developed lighting configurations for cases with transparent doors. DOE has retained these configurations as part of this analysis, and has further developed additional configurations for equipment classes not covered in the 2009 rulemaking. For the VCT equipment family, DOE assumed one fluorescent bulb on each mullion and a fluorescent bulb on each end of the case. There are two different types of LED lighting used in cases with transparent doors. A center mullion lighting fixture is used between doors and is designed to have half of the LED emitters directed toward one door and half of the LED chips directed toward the other door. An end mullion lighting fixture has half the light output, cost, and power consumption of a center mullion lighting fixture. The LED emitters in an end mullion lighting fixture are all directed toward the one door next to which they are located. Therefore, two end mullion lighting fixtures are the approximately equivalent to a single center mullion lighting fixture with regard to cost, light output, and power consumption. DOE modeled the LED lighting for the VCT equipment family using a center mullion lighting fixture and assumed one center mullion lighting fixture per door. Illustrative front views of the lighting configurations for both fluorescent and LED lighting for the VCT equipment family are shown in Figure 5A.3.1 through Figure 5A.3.6. The red strips represent a fluorescent bulb inside the refrigerated volume, the blue strips represent an LED center mullion lighting fixture inside the refrigerated volume, and the green strips represent an LED end mullion lighting fixture inside the refrigerated volume.

Bulb In =
LED In = ← Center Mullion
1/2 LED In = ← End Mullion (one on either end of case, resulting in the equivalent of a single center mullion)

VCT.RC.M
Lighting Type: Fluorescent
Case Length [ft]: 12.7
Bulb Length [ft]: 5
Bulbs In: 6
Bulbs Out: 0



VCT.RC.M
Lighting Type: LED
Case Length [ft]: 12.7
Bulb Length [ft]: 5
LEDs In: 5
LEDs Out: 0

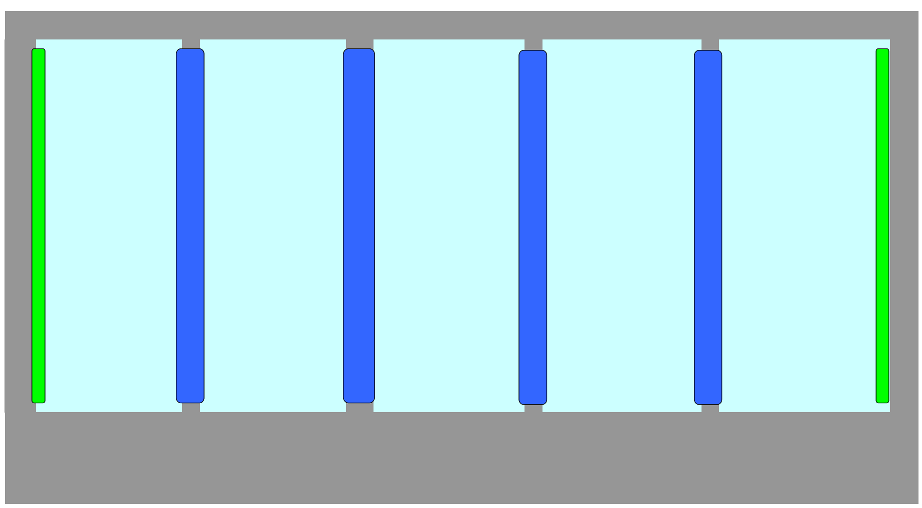
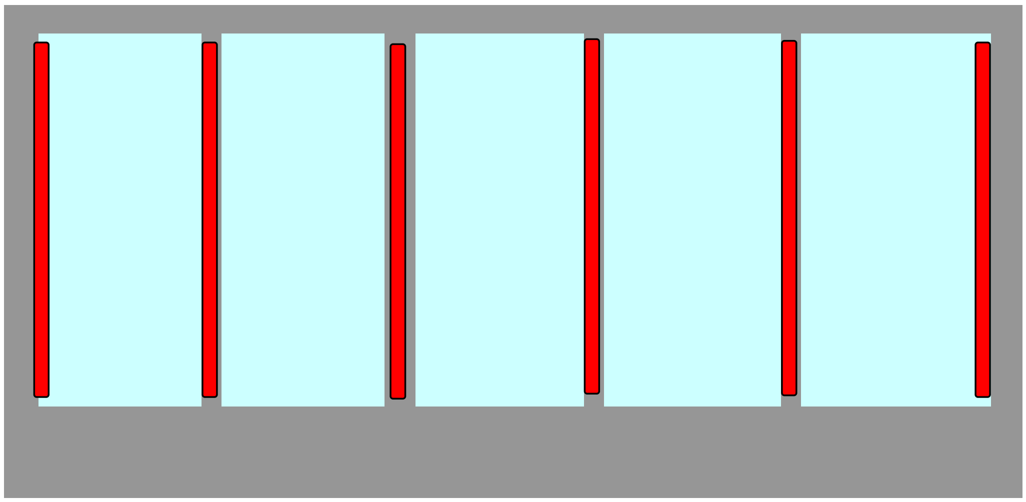


Figure 5A.3.1 Lighting Configurations for VCT.RC.M

VCT.RC.L

Lighting Type:	Fluorescent
Case Length [ft]:	12.7
Bulb Length [ft]:	5
Bulbs In:	6
Bulbs Out:	0



VCT.RC.L

Lighting Type:	LED
Case Length [ft]:	12.7
Bulb Length [ft]:	5
LEDs In:	5
LEDs Out:	0

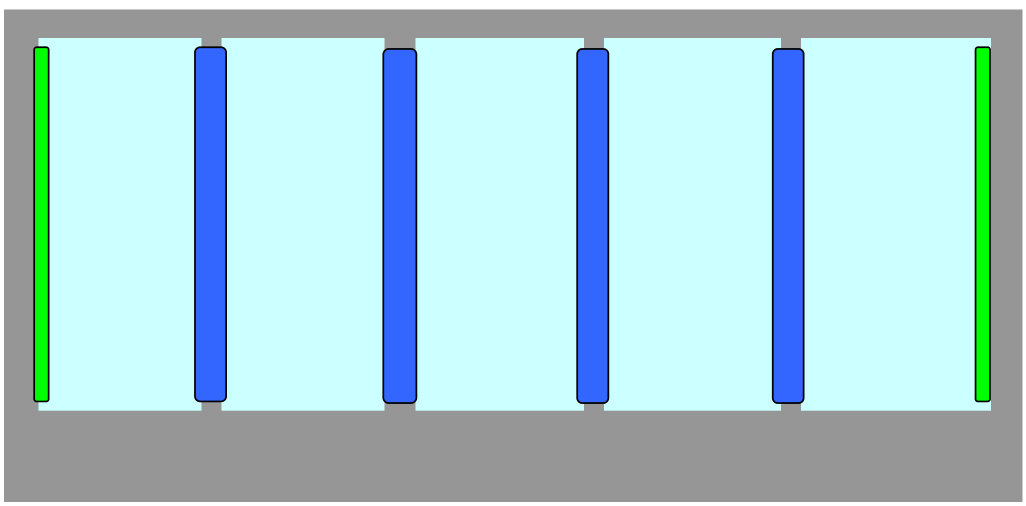


Figure 5A.3.2 Lighting Configurations for VCT.RC.L

VCT.SC.M		**VCT.SC.M**	
Lighting Type:	Fluorescent	Lighting Type:	LED
Case Length [ft]:	4.5	Case Length [ft]:	4.5
Bulb Length [ft]:	5	Bulb Length [ft]:	5
Bulbs In:	3	LEDs In:	2
Bulbs Out:	0	LEDs Out:	0

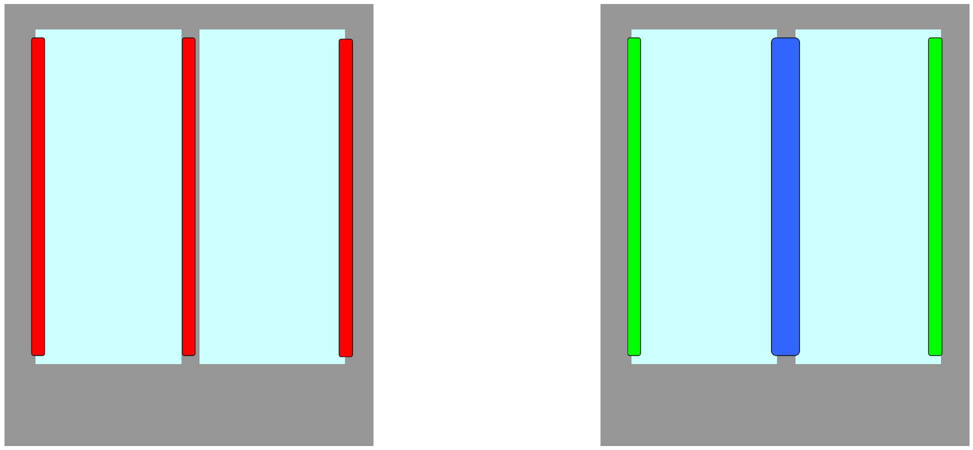


Figure 5A.3.3 Lighting Configurations for VCT.SC.M

VCT.SC.L		**VCT.SC.L**	
Lighting Type:	Fluorescent	Lighting Type:	LED
Case Length [ft]:	4.5	Case Length [ft]:	4.5
Bulb Length [ft]:	5	Bulb Length [ft]:	5
Bulbs In:	3	LEDs In:	2
Bulbs Out:	0	LEDs Out:	0

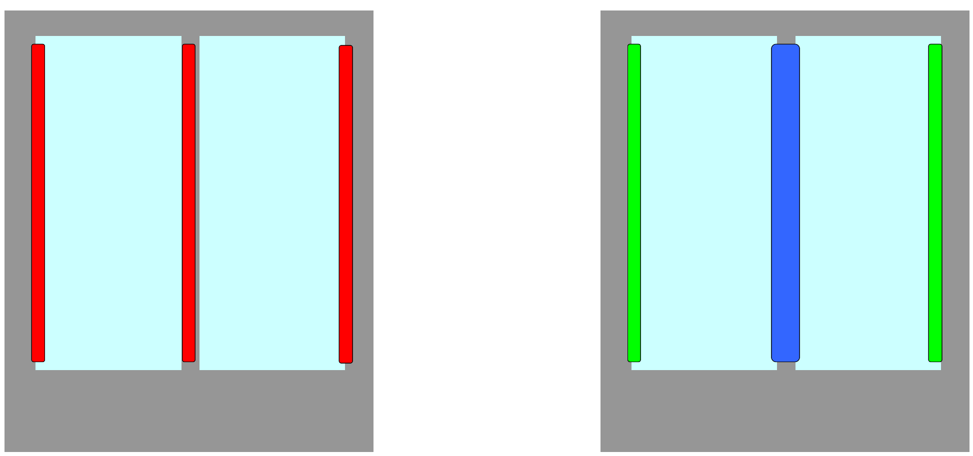


Figure 5A.3.4 Lighting Configurations for VCT.SC.L

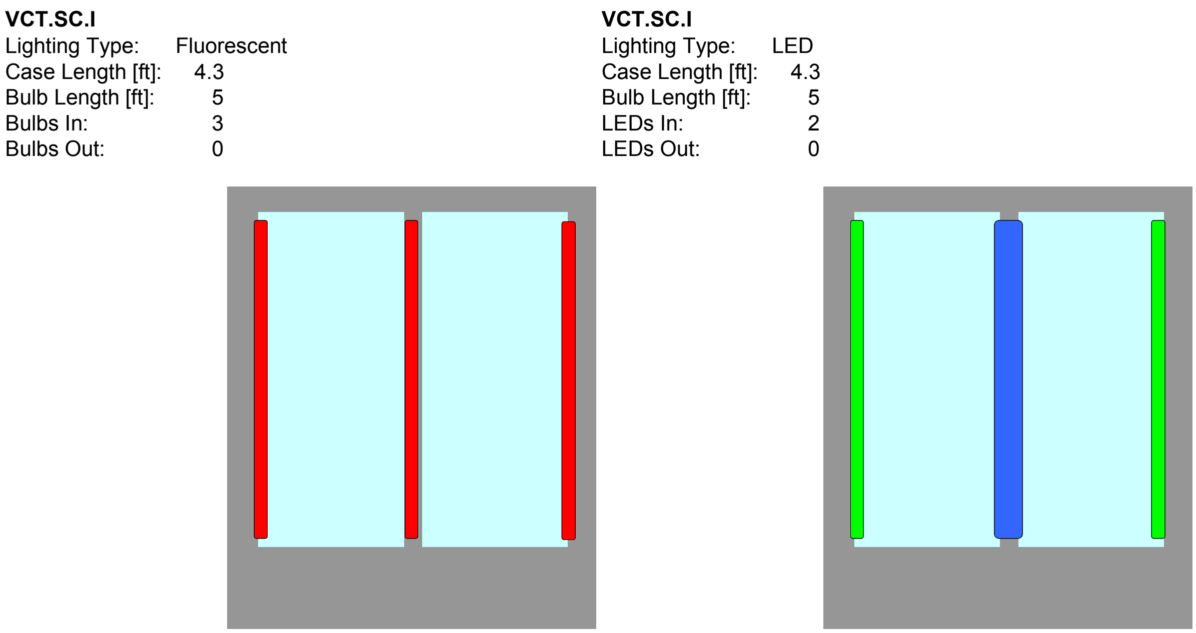


Figure 5A.3.5 Lighting Configurations for VCT.SC.I

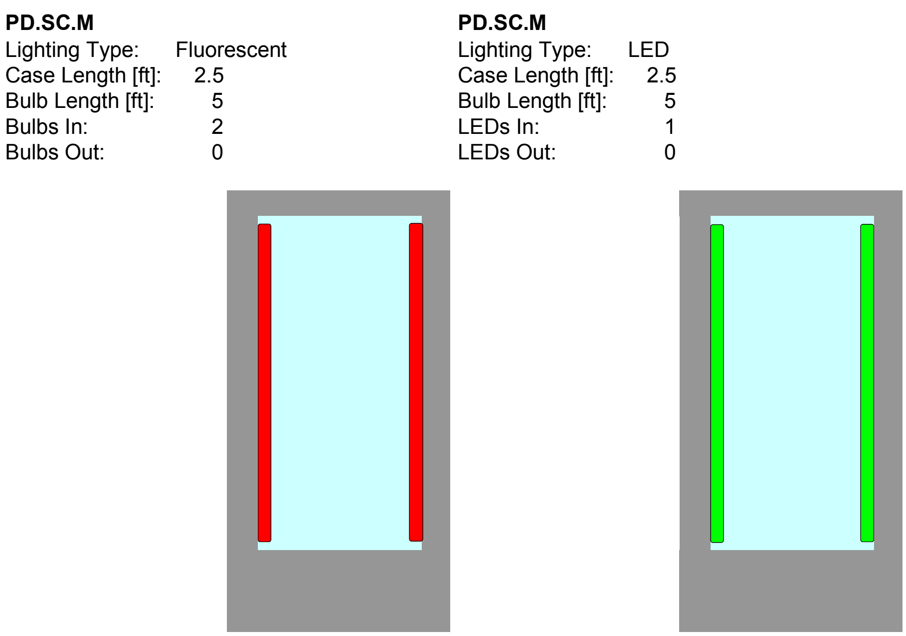


Figure 5A.3.6 Lighting Configurations for PD.SC.M

For equipment classes without doors *(i.e.*, VOP, SVO, and HZO equipment families), as well as service over counter equipment, merchandise throughout the entire refrigerated volume is visible to the consumer. Therefore, the entire refrigerated volume must be illuminated.[b] For this application, the directionality characteristic of LED lighting tends to be less effective than fluorescent lighting, which outputs light in all directions surrounding the bulb. In the 2009 final

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[b] DOE assumes that the HZO equipment family does not contain any lighting because the ambient light of the store provides adequate illumination of the displayed merchandise. This is consistent with current manufacturer practice.

rule, DOE developed case lighting configurations for these classes as well. Based on discussions with LED refrigerated display case lighting manufacturers and comments from commercial refrigeration equipment manufacturers, DOE determined that there are two different types of LED luminaries used in this equipment. A shelf light is used to illuminate merchandise close to it. Due to the directionality of the light output from an LED luminary, DOE assumes that two shelf lights are used per shelf to provide the desired illumination throughout an entire shelf: one on the front of the shelf and one midway under the shelf. A canopy light is typically located on the canopy of a display case. A canopy light has effectively twice the light output, cost, and power consumption of a shelf light and is typically is used to provide additional illumination of the product in the bottom well of the display case. DOE modeled the LED lighting for the VOP, SVO, and SOC equipment families, in the engineering analysis, using a shelf light. DOE also assumed that the number of LED lighting fixtures per shelf would have to be doubled from what was assumed for fluorescent lighting to provide adequate illumination for the merchandise displayed on each shelf. Illustrative cross-sections of lighting configurations for both fluorescent and LED lighting for example classes in the VOP, SVO, and SOC equipment families are shown in Figure 5A.3.7 through Figure 5A.3.12. The green circles represent a bulb or LED inside the refrigerated volume and the red circles represent a bulb or LED outside the refrigerated volume.

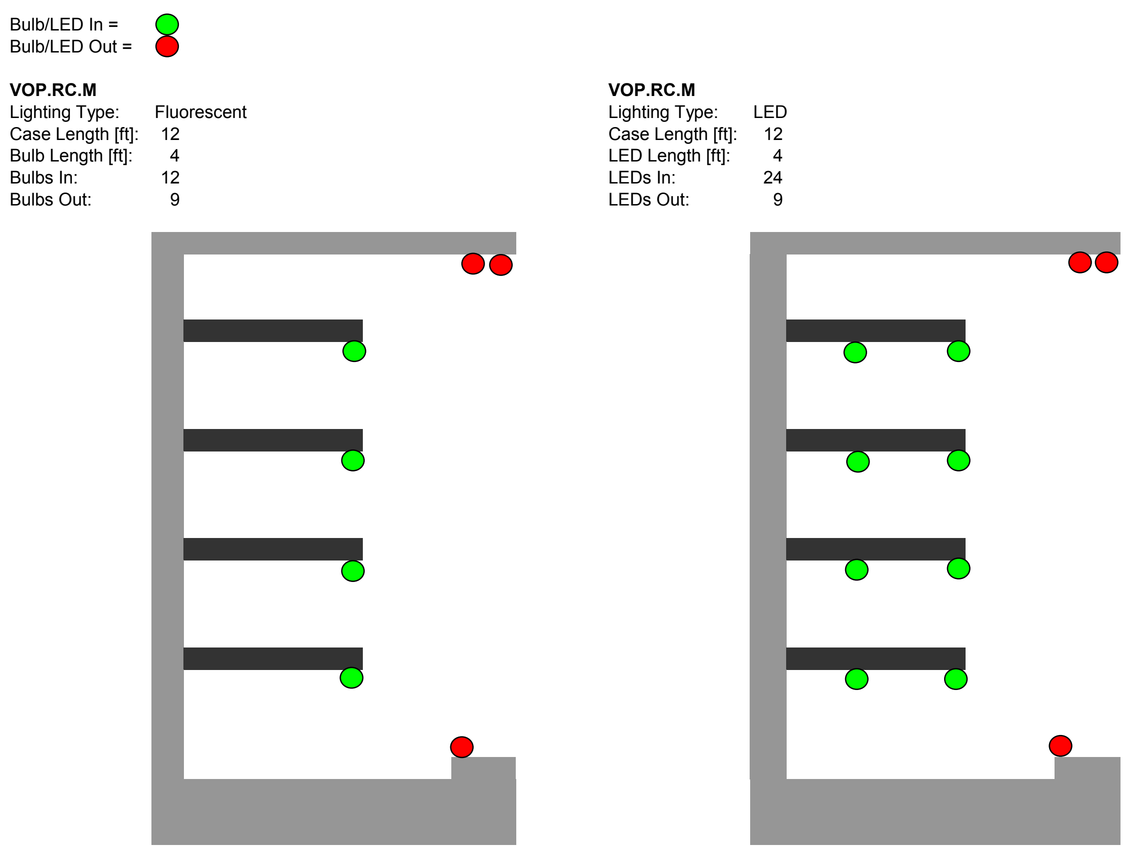
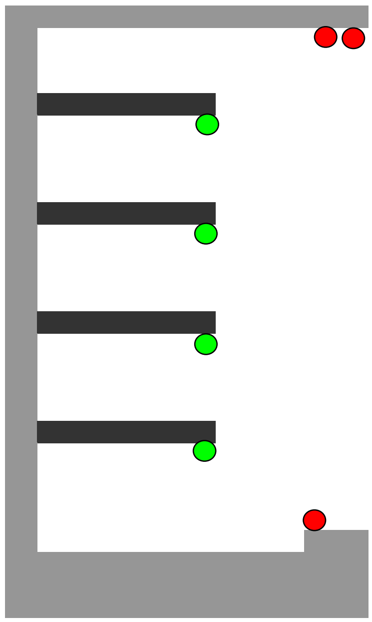


Figure 5A.3.7 Lighting Configurations for VOP.RC.M

VOP.SC.M
Lighting Type: Fluorescent
Case Length [ft]: 4
Bulb Length [ft]: 4
Bulbs In: 4
Bulbs Out: 3



VOP.SC.M
Lighting Type: LED
Case Length [ft]: 4
LED Length [ft]: 4
LEDs In: 8
LEDs Out: 3

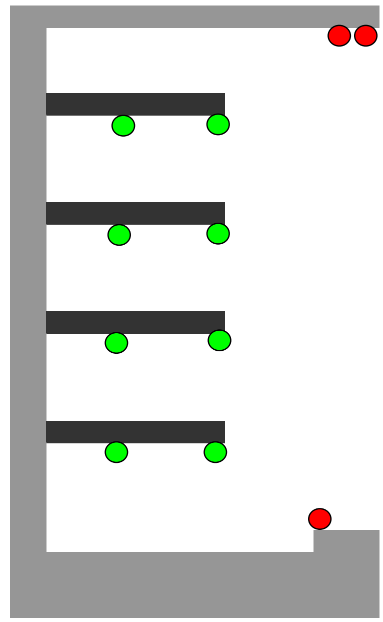
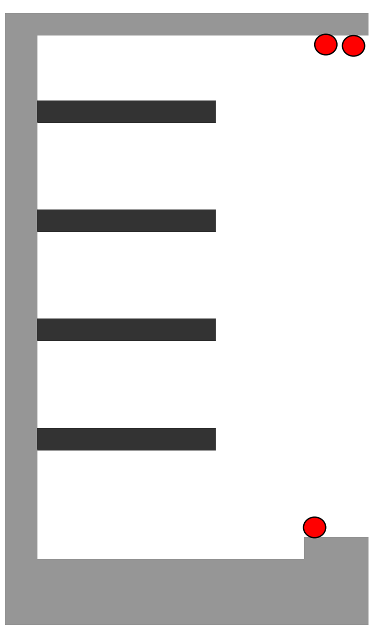


Figure 5A.3.8 Lighting Configurations for VOP.SC.M

VOP.RC.L
Lighting Type: Fluorescent
Case Length [ft]: 12
Bulb Length [ft]: 4
Bulbs In: 0
Bulbs Out: 9



VOP.RC.L
Lighting Type: LED
Case Length [ft]: 12
LED Length [ft]: 4
LEDs In: 0
LEDs Out: 9

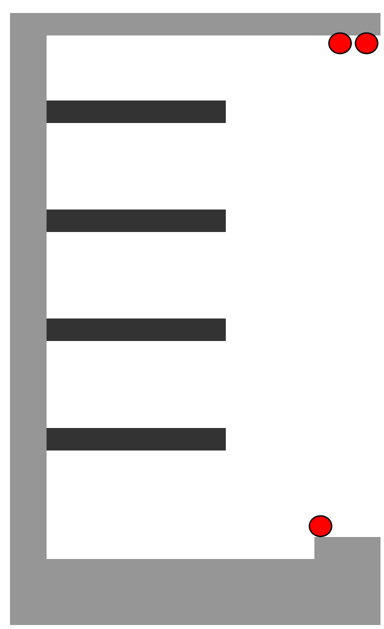


Figure 5A.3.9 Lighting Configurations for VOP.RC.L

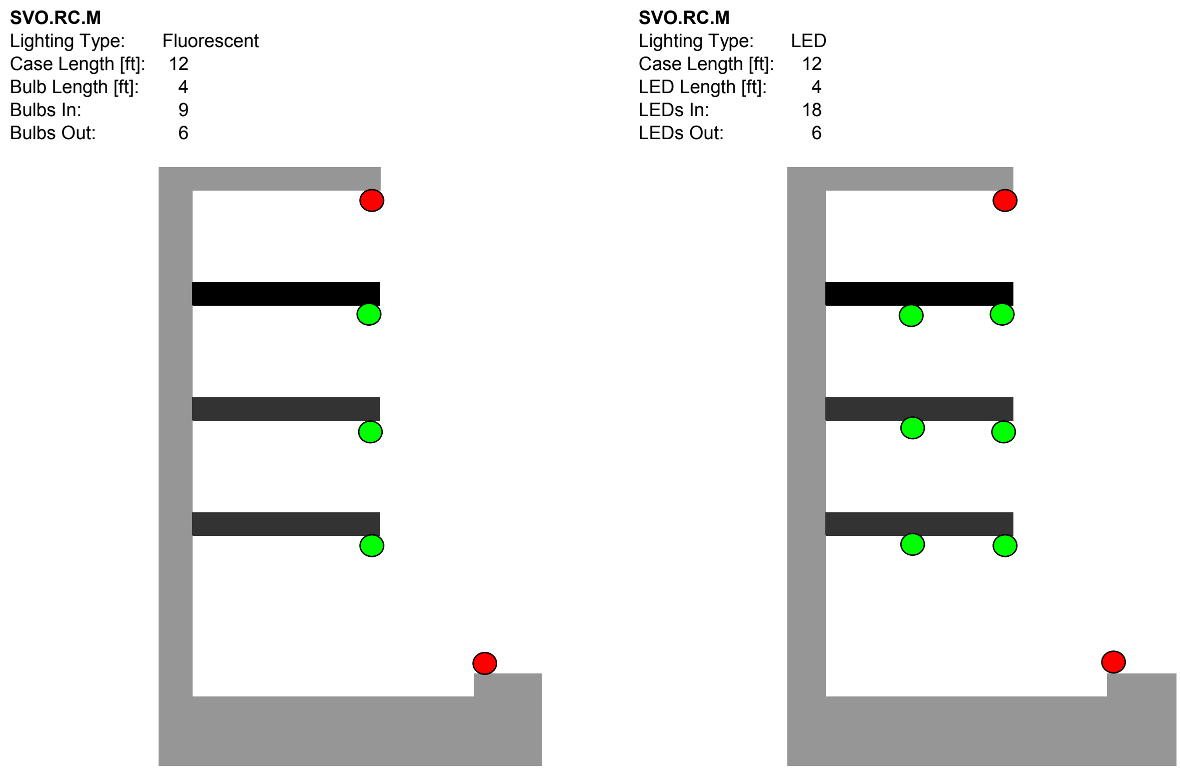


Figure 5A.3.10 Lighting Configurations for SVO.RC.M

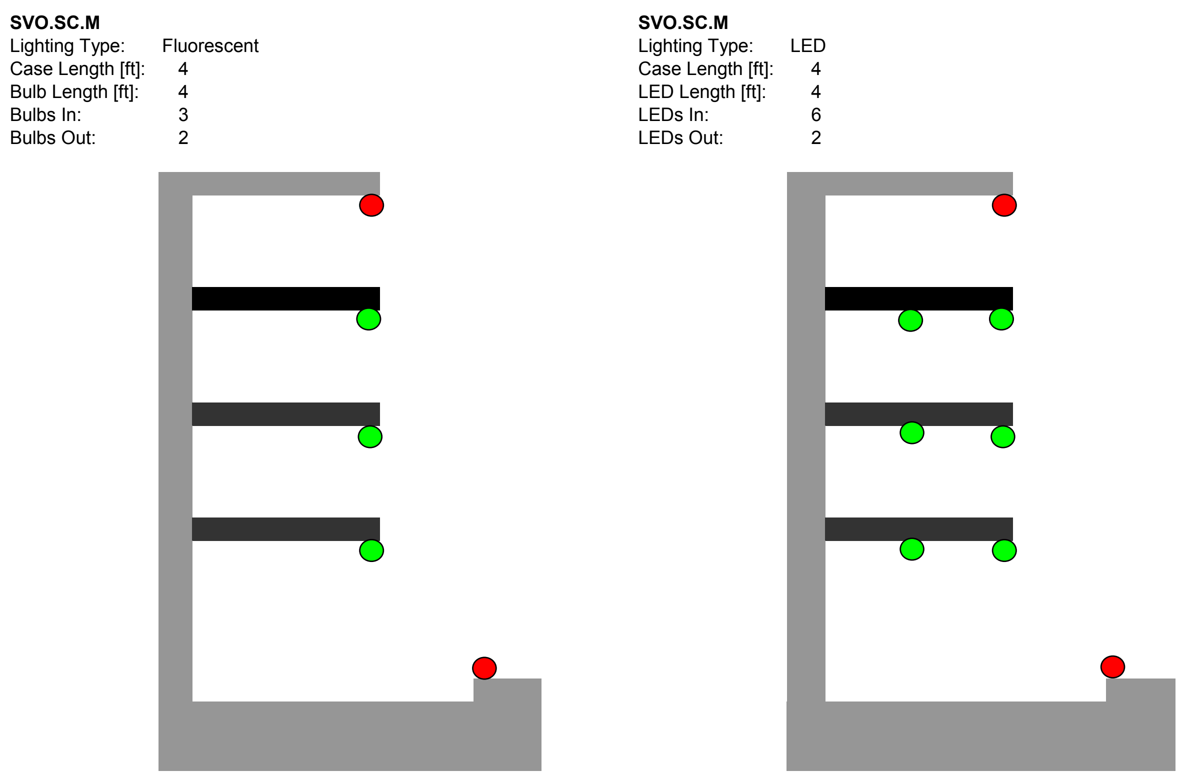
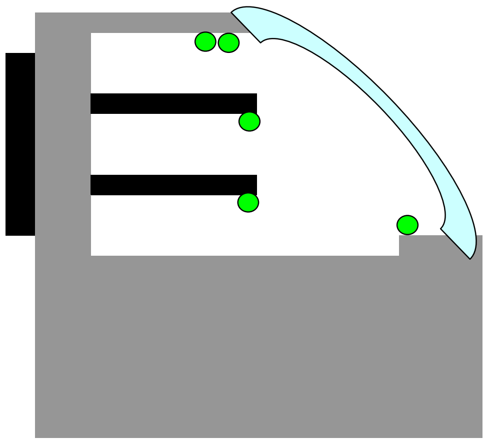


Figure 5A.3.11 Lighting Configurations for SVO.SC.M

SOC.RC.M
Lighting Type: Fluorescent
Case Length [ft]: 12
Bulb Length [ft]: 4
Bulbs In: 15
Bulbs Out: 0



SOC.RC.M
Lighting Type: LED
Case Length [ft]: 12
LED Length [ft]: 4
LEDs In: 18
LEDs Out: 0

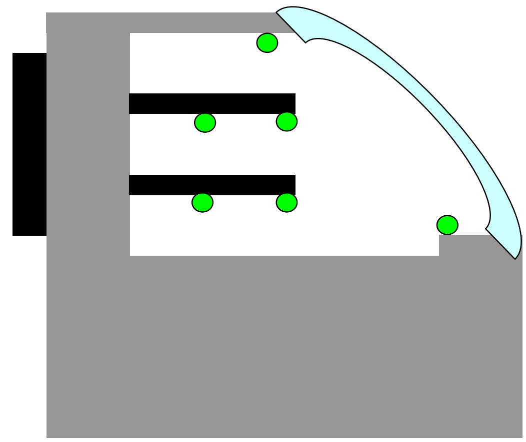


Figure 5A.3.12 Lighting Configurations for SOC.RC.M

CHAPTER 6. MARKUPS FOR EQUIPMENT PRICE DETERMINATION

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CHAPTER 6. MARKUPS FOR EQUIPMENT PRICE DETERMINATION

6.1 INTRODUCTION

One of the most important inputs to the life-cycle cost (LCC) and payback period (PBP) analysis and the national impact analysis (NIA) is the installed cost of the commercial refrigeration equipment. Installed cost includes equipment purchase price and installation costs. The U.S. Department of Energy (DOE) determines the equipment purchase price by using multipliers called "markups" that are applied to the manufacturer production cost (MPC) to obtain the customer purchase price of the equipment. The manufacturer markup, calculated as part of the engineering analysis (see chapter 5 of the technical support document (TSD)), converts the MPC into manufacturer selling price (MSP). Additional markups, called distribution channel markups, are applied to the MSP based on the distribution channels through which customers purchase the equipment to obtain the customer purchase price of the equipment. This chapter describes the methodology used by DOE to calculate the distribution channel markups and also the methodology by which the markups values are used to obtain the customer purchase price of the commercial refrigeration equipment.

DOE determined that commercial refrigeration equipment is purchased by the customers through three major distribution channels:

Manufacturer → Customer (**National Account Channel**)

Manufacturer → Wholesaler → Customer (**Wholesaler Channel**)

Manufacturer → Wholesaler → Mechanical Contractor → Customer (**Contractor Channel**)

In addition to the manufacturer markup and distribution channel markups, sales tax is applied to obtain the customer purchase price of the equipment. Sales tax varies by the state in which the equipment is installed.

DOE first calculated national-average markup values for each distribution channel. DOE carried out the LCC analysis in the form of Monte Carlo simulations, and one of the inputs to each analysis simulation was the state (location) in which the equipment was installed (see TSD chapter 8 for detailed description). For each analysis simulation in the LCC analysis, the values used for the national account channel markup and wholesaler channel markup were the national average values. However, the contractor channel markup was varied by state (explained later in this chapter). The three distribution channel markup values were weighted-averaged using the market share of each distribution channel to obtain weighted-average distribution channel markups for each analysis simulation in the LCC analysis. In addition to the distribution channel markups, a sales tax was applied to obtain the customer purchase price of the equipment.

6.2 BASELINE, INCREMENTAL, AND OVERALL MARKUPS

Baseline markups are the markups that convert the MSP of equipment of the baseline efficiency level to customer purchase price. Incremental markups are markups that convert the increase in MSP of equipment at higher efficiency levels to an increase in customer purchase price compared to the price of equipment at the baseline efficiency level. Overall markups include the weighted-average distribution channel markups, based on the distribution channel market share, and sales tax.

6.2.1 Baseline Markups

If the baseline equipment is sold to a customer by the manufacturer through the national account channel, the following equation defines the equipment price:

$$\boldsymbol{EQP_{NATL\ ACCT\ BASE} = MFG_{BASE} \times MU_{NATL\ ACCT\ BASE} \times (1 + ST)}$$

Eq. 6.1

Where:

$EQP_{NATL\ ACCNT\ BASE}$ = national account price to the customer of baseline equipment ($),
MFG_{BASE} = MSP of baseline equipment ($),
$MU_{NATL\ ACCT\ BASE}$ = national account markup on baseline equipment, and
ST = sales tax rate.

If the baseline equipment is sold to a customer through the wholesaler channel:

$$\boldsymbol{EQP_{WHOLE\ BASE} = MFG_{BASE} \times MU_{WHOLE\ BASE} \times (1 + ST)}$$

Eq. 6.2

Where:

$EQP_{WHOLE\ BASE}$ = wholesaler price of baseline equipment ($), and
$MU_{WHOLE\ BASE}$ = wholesaler markup on baseline equipment.

If the baseline equipment is sold to a customer through the contractor channel:

$$\boldsymbol{EQP_{MECH\ CONT\ BASE} = MFG_{BASE} \times MU_{WHOLE\ BASE} \times MU_{MECH\ CONT\ BASE} \times (1 + ST)}$$

Eq. 6.3

Where:

$EQP_{MECH\ CONT\ BASE}$ = mechanical contractor price of baseline equipment ($), and
$MU_{MECH\ CONT\ BASE}$ = mechanical contractor markup on baseline equipment.

6.2.2 Incremental Markups

Incremental markups are cost multipliers that relate increments in the MSP of equipment at higher efficiency levels to the corresponding increments in the customer purchase price. Similar to the baseline markups, DOE calculated one incremental markup value for each distribution channel. The increment in MSP of equipment at higher efficiency levels is obtained by subtracting the MSP of equipment at the baseline efficiency level (MFG_{BASE}) from the MSP of equipment at higher efficiency levels.

$$\boldsymbol{MFG_{INCR} = MFG_{HIGHER\ EFF\ LEVEL} - MFG_{BASE}}$$

Eq. 6.4

Where:

MFG_{INCR} = increment in MSP of higher efficiency equipment ($), and
$MFG_{HIGHER\ EFF\ LEVEL}$ = MSP of equipment at higher efficiency level ($).

If the equipment is sold to a customer by the manufacturer through a national account, the following equation defines the increase in equipment price:

$$\boldsymbol{EQP_{NATL\ ACCT\ INCR} = MFG_{INCR} \times MU_{NATL\ ACCT\ INCR} \times (1 + ST)}$$

Eq. 6.5

Where:

$EQP_{NATL\ ACCNT\ INCR}$ = increment in customer purchase price to the national account customer ($), and
$MU_{NATL\ ACCT\ INCR}$ = national account channel incremental markup.

If the customer acquires the higher efficiency equipment through the wholesaler or contractor channels:

$$\boldsymbol{EQP_{WHOLE\ INCR} = MFG_{INCR} \times MU_{WHOLE\ INCR} \times (1 + ST)}$$

Eq. 6.6

Where:

$EQP_{WHOLE\ INCR}$ = incremental wholesaler price ($), and
$MU_{WHOLE\ INCR}$ = wholesaler channel incremental markup.

$$\boldsymbol{EQP_{MECH\ CONT\ INCR} = MFG_{INCR} \times MU_{WHOLE\ INCR} \times MU_{MECH\ CONT\ INCR} \times (1 + ST)}$$

Eq. 6.7

Where:

$EQP_{MECH\ CONT\ INCR}$ = incremental mechanical contractor price ($), and
$MU_{MECH\ CONT\ INCR}$ = mechanical contractor channel incremental markup.

6.2.3 Distribution Channel Market Shares

For the 2009 final rule analysis, market shares of the three distribution channels were based on estimates provided by Carrier Corporation to DOE during the public review of the advanced notice of proposed rulemaking. 73 FR 50094 (Aug. 25, 2008). Also, during the preliminary analysis, DOE obtained additional data from articles on the *Foodservice Equipment & Supplies* (FE&S) magazine website,[1] which provided market shares for distribution channels for all foodservice equipment sales. Refrigeration equipment used in the foodservice industry is primarily composed of self-contained equipment. Refrigeration equipment constitutes only 8 percent of the total equipment sales to the foodservice industry,[1] and the distribution channel shares for refrigeration equipment may be different from the rest of the foodservice equipment. However, due to lack of availability of additional data, DOE used the market share values of the overall foodservice equipment sales for all self-contained commercial refrigeration equipment.

During the preliminary analysis public meeting, many stakeholders commented that national accounts compose a larger share of the glass-door cases and that DOE's market share values for self-contained equipment were applicable only to solid-door cases. Some manufacturers implied that their market share distribution for glass-doored cases was closer to that of the remote-condensing cases as they sold a major share of their glass-doored cases through national account channels. DOE also recognized that the data from FE&S magazine website[1] was applicable more to solid-doored cases, which form a majority of equipment used in the foodservice industry. Therefore, DOE agreed with these comments from the stakeholders and consequently altered the market share of the distribution channels by grouping equipment families into two groups: (1) Display cases (VOP, SVO, HZO, VCT, HCT, SOC and PD), and (2) solid-door equipment (VCS and HCS). Table 6.2.1 provides the market shares of the three distribution channels for display cases and solid-door equipment used for the notice of proposed rulemaking (NOPR). DOE applied the market shares for remote-condensing equipment from the January 2009 final rule to display cases and used the FE&S magazine website data for the solid-door equipment.

Table 6.2.1 Distribution Channels Market Shares for Commercial Refrigeration Equipment

Equipment Type	National Account Channel	Wholesaler Channel	Contractor Channel
Display Cases (VOP, SVO, HZO, VCT, HCT, SOC, and PD)	70 %	15%	15%
Solid-Door Equipment (VCS and HCS)	30%	60%	10%

6.2.4 Overall Markups

Overall markup values were separately obtained for both baseline and incremental markups by combining the state sales tax with the weighted-average distribution channel markups. Overall baseline markup values were calculated using the following:

$$\begin{aligned} EQP_{CUST\ BASE} &= MFG_{BASE} \\ &\times (WT_{NATL\ ACCT} \times MU_{NATL\ ACCT\ BASE} + WT_{WHOLESALER} \times MU_{WHOLE\ BASE} \\ &+ WT_{MECH\ CONT} \times MU_{WHOLE\ BASE} \times MU_{MECH\ CONT\ BASE}) \\ &\times (1 + ST) \\ &= MFG_{BASE} \times MU_{OVERALL\ BASE} \end{aligned}$$

Eq. 6.8

Where:

$EQP_{CUST\ BASE}$ = customer purchase price for baseline equipment ($),
$WT_{NATL\ ACCT}$ = market share of baseline equipment sales through national account channel (%),

$WT_{WHOLESALER}$ = market share of baseline equipment sales through wholesaler channel (%),
$WT_{MECH\ CONT}$ = market share of baseline equipment sales through contractor channel (%), and
$MU_{OVERALL\ BASE}$ = overall baseline markup.

Overall incremental markups were calculated using the following equation:

$$EQP_{CUST\ INCR} = MFG_{INCR} \times (WT_{NATL\ ACCT} \times MU_{NATL\ ACCT\ INCR} + WT_{WHOLESALER} \times MU_{WHOLE\ INCR} + WT_{MECH\ CONT} \times MU_{WHOLE\ INCR} \times MU_{MECH\ CONT\ INCR}) \times (1 + ST)$$

$$= MFG_{INCR} \times MU_{OVERALL\ INCR}$$

Eq. 6.9

Where:

$EQP_{CUST\ INCR}$ = increment in customer purchase price of equipment at a higher efficiency level compared to baseline equipment ($),
$MU_{OVERALL\ INCR}$ = overall incremental markup.

For a particular piece of equipment at a higher efficiency level, the total price of that equipment to the customer (EQP_{CUST}) is the sum of the baseline customer price ($EQP_{CUST\ BASE}$) and the incremental customer price ($EQP_{CUST\ INCR}$).

$$\mathrm{EQP_{CUST}} = \mathrm{EQP_{CUST\ BASE}} + \mathrm{EQP_{CUST\ INCR}}$$

Eq. 6.10

6.3 BASIC ASSUMPTIONS USED TO ESTIMATE WHOLESALER AND MECHANICAL CONTRACTOR MARKUPS

DOE based the wholesaler markups on industry balance-sheet data and based the mechanical contractor markups on U.S. Census Bureau data for the plumbing, heating, and air conditioning (PHAC) industry.[2] DOE obtained the industry balance-sheet data from the Heating, Air conditioning & Refrigeration Distributors International (HARDI), the trade association representing wholesalers of heating, ventilation, air-conditioning, and refrigeration (HVACR) equipment.[3] DOE compiled the U.S. Census Bureau PHAC data following the same format as the balance-sheet data for wholesalers. These balance sheets break out the components of all costs incurred by firms that supply and install PHAC equipment. DOE derived the wholesaler and mechanical contractor markups from three key assumptions about commercial refrigeration equipment costs:

1. The firm balance sheets accurately represent the various average costs incurred by firms distributing and installing commercial refrigeration equipment.

2. The wholesaler and contractor costs can be divided into two categories: (1) costs that vary in proportion to the MSP of commercial refrigeration equipment (variable costs);

and (2) costs that do not vary with the MSP of commercial refrigeration equipment (fixed costs).

3. Wholesaler and contractor prices vary in proportion to wholesaler and contractor costs included in the balance sheets.

The basis for the first assumption is that the industry balance sheets 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. Although wholesalers and contractors tend to handle multiple commodity lines (including air conditioners, furnaces, and boilers) the data provides the most accurate available data for commercial refrigeration equipment costs.

Information obtained from trade literature and from selected HVACR wholesalers, contractors, and consultants, supports the second assumption that wholesale and contractor markups vary according to the quantity of labor and materials used to distribute and install HVACR equipment. In the following discussion, DOE assumes a division of costs between those that do not scale with the MSP (labor and occupancy expenses) and those that do vary with MSP (operating expenses and profit). This division of costs led to the estimate of wholesale and contractor markups described in section 6.4.

The basis for the third assumption is that the HVACR wholesaler and contractor industry is competitive and consumer demand for commercial refrigeration, heating and air conditioning equipment is inelastic, (*i.e.*, the demand is not expected to decrease significantly with an increase in price of equipment). The large number of HVACR firms listed in the 2007 economic census indicates the competitive nature of the market. For example, there are more than 700 HVACR manufacturers,[4] 1,300 wholesalers of refrigeration equipment,[5] 36,000 commercial and institutional building contractors,[6] and 91,000 HVAC contractors[7] listed in the 2007 economic census. Following standard economic theory, competitive firms facing inelastic demand either set prices in line with costs or quickly go out of business.[8]

6.4 ESTIMATION OF WHOLESALER MARKUPS

Annually, HARDI conducts a confidential survey of its member firms in which wholesalers report data. In the survey, HARDI itemizes revenues and costs into cost categories, including direct equipment expenses (cost of goods sold), labor expenses, occupancy expenses, other operating expenses, and profit. DOE presents the data for a typical HARDI distributor in terms of specific types of expense within these categories in appendix 6A. Table 6.4.1 summarizes these expenses in units of expenses per dollar sales revenue and revenue per dollar of goods sold. As shown in the first column of Table 6.4.1, the direct cost of equipment sold represents $0.737 per dollar of sales revenue. In other words, for every $1.00 wholesalers take in as sales revenue, they use $0.737 to pay for the direct equipment costs. Labor expenses account for $0.151 per dollar of sales revenue, occupancy expenses account for $0.036, other operating expenses account for $0.055, and profit accounts for $0.021 per dollar sales revenue.

Table 6.4.1 Wholesaler Expenses and Markups*

Description	Wholesale Firm Expenses or Revenue	
	Per Dollar Sales Revenue	**Per Dollar Cost of Goods Sold**
Direct Cost of Equipment Sales: Cost of goods sold	$0.737	$1.000
Labor Expenses: Salaries and benefits	$0.151	$0.205
Occupancy Expense: Rent, maintenance, and utilities	$0.036	$0.049
Other Operating Expenses: Depreciation, advertising, and insurance	$0.055	$0.075
Profit	$0.021	$0.029
Baseline Markup ($MU_{WHOLE\ BASE}$): Revenue per dollar cost of goods sold *		1.357
Incremental Markup ($MU_{WHOLE\ INCR}$): Increased revenue per dollar increase cost of goods sold**		1.103

* Source: Heating, Airconditioning & Refrigeration Distributors International. 2012. *2012 Profit Report (2011 Data)*. Based on a Typical HARDI Distributor.
** Numbers include rounding errors and may not add up to the totals.

The last column of Table 6.4.1 shows the data converted from costs per dollar revenue into revenue per dollar cost of goods sold. DOE performed this conversion by dividing each cost category in the first data column of Table 6.4.1 by $0.737 (*i.e.*, equipment expenditure per dollar revenue). The data in this column show that, for every $1.00 the wholesaler spends on equipment costs, the wholesaler earns $1.00 in sales revenue to cover the equipment cost, $0.205 to cover labor costs, $0.049 to cover occupancy expenses, $0.075 for other operating expenses, and $0.029 in profits. This totals to $1.357 in sales revenue earned for every $1.00 spent on equipment costs. Therefore, the wholesaler baseline markup ($MU_{WHOLE\ BASE}$) is 1.357 ($1.357 ÷ $1.00).

DOE also used the data in the last column of Table 6.4.1 to estimate the incremental markups. The incremental markup depends on which of the costs in Table 6.4.1 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 manufacturer selling price (*i.e.*, all costs are variable), the increase in wholesaler price will be $1.357, implying that the incremental markup is 1.357, or the same as the baseline markup. However, if none of the other costs is variable, then a $1.00 increase in the manufacturer selling price will lead to a $1.00 increase in the wholesaler price, for an incremental markup of 1.0. DOE assumes that the labor and occupancy costs will be 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 manufacturer selling price, the wholesaler price will increase by $0.103, which is the sum of other operating expenses and profit in the last column of Table 6.4.1. Therefore, the wholesaler incremental markup ($MU_{WHOLE\ INCR}$) is 1.103 ($1.103 ÷ $1.00). See appendix 6A for additional details and data used for markup calculations.

6.5 ESTIMATION OF MECHANICAL CONTRACTOR MARKUPS

DOE derived markups for mechanical contractors from U.S. Census Bureau data for plumbing, heating, and air-conditioning contractors. This sector includes establishments primarily engaged in installing and servicing plumbing, heating, and air-conditioning equipment, which may include new work, additions, alterations, maintenance, and repairs. The U.S. Census Bureau data for the PHAC sector include detailed statistics for establishments with payrolls, similar to the data reported by HARDI for wholesalers. The primary difference is that the U.S. Census Bureau reports itemized revenues and expenses for the PHAC industry as a whole in total dollars rather than in typical values for an average or representative business. Because of this, DOE assumed that the total dollar values that the U.S. Census Bureau reported, once converted to a percentage basis, represented revenues and expenses for an average or typical contracting business. As with the data for wholesalers, Table 6.5.1 summarizes the expenses for mechanical contractors. The expenses per dollar sales revenue are given in the first data column of Table 6.5.1 (appendix 6A contains the full set of data). The direct cost of sales represents about $0.680 per dollar sales revenue to the mechanical contractor. Labor expenses account for $0.170 per dollar sales revenue, occupancy expenses account for $0.020 per dollar sales revenue, other operating expenses account for $0.040, and profit makes up $0.090 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 $0.678. The data in the last column of Table 6.5.1 show that, for every $1.00 the mechanical contractor spends on equipment costs, the mechanical contractor earns $1.00 in sales revenue to cover the equipment cost, $0.258 to cover labor costs, $0.032 to cover occupancy expenses, $0.058 for other operating expenses, and $0.127 in profits. This totals $1.475 in sales revenue earned for every $1.00 spent on equipment costs. Therefore, the mechanical contractor baseline markup ($MU_{MECH\ CONT\ BASE}$) is 1.475 ($1.471 ÷ $1.00).

Table 6.5.1 Mechanical Contractor Expenses and Markups*

Description	Mechanical Contractor Firm Expenses or Revenue: Per Dollar Sales Revenue	Mechanical Contractor Firm Expenses or Revenue: Per Dollar Cost of Goods Sold
Direct Cost of Equipment Sales: Cost of goods sold	$0.678	$1.000
Labor Expenses: Salaries (indirect) and benefits	$0.175	$0.258
Occupancy Expense: Rent, maintenance, and utilities	$0.022	$0.032
Other Operating Expenses: Depreciation, advertising, and insurance	$0.039	$0.058
Net Profit Before Taxes	$0.086	$0.127
Baseline Markup ($MU_{MECH\ CONT\ BASE}$): Revenue per dollar cost of goods sold **		1.475
Incremental Markup ($MU_{MECH\ CONT\ INCR}$): Increased revenue per dollar increase cost of goods sold **		1.185

* Source: U.S. Census Bureau. 2007. Plumbing, Heating, and Air-Conditioning Contractors. Sector 23: 238220. Construction: Geographic Area Series: Detailed Statistics for Establishments: 2007.
** Numbers include rounding errors and may not add up to the totals.

DOE was also able to use the data in the last column in Table 6.5.1 to estimate the incremental markups by separating the fixed and variable costs. For example, if all of the other costs scale with the equipment price (*i.e.*, all costs are variable), the increase in mechanical contractor price will be $1.475, implying that the incremental markup is 1.475, or the same as the baseline markup. However, if none of the other costs is variable, then a $1.00 increase in the equipment price will lead to a $1.00 increase in the mechanical contractor price, for an incremental markup of 1.0. DOE assumes 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 mechanical contractor price will increase by $0.185, which is the sum of other operating expenses and profit in the last column of Table 6.5.1, giving a mechanical contractor incremental markup ($MU_{MECH\ CONT\ INCR}$) of 1.185 ($1.185 ÷ $1.00).

Mechanical contractor costs differ in various regions of the country for reasons including availability of labor, cost of living, and union versus non-union workforce. Because many mechanical contractor costs differ systematically by state, DOE characterized the markups developed from U.S. Census Bureau data with a probability distribution based on a state-by-state analysis of U.S. Census Bureau data for PHAC contractors. The state-by-state analysis provided a distribution on the relative markups of mechanical contractors in the United States.

Figure 6.5.1 shows the cumulative probability distribution of the state markup index that DOE used to characterize the mechanical contractor baseline and incremental markups. As mentioned in section 6.1, the contractor channel markup index was varied by state. The baseline and incremental markups in Table 6.5.1 are the national average markup values for the contractor channel. In the LCC analysis (TSD chapter 8), these national average values were multiplied by the state markup index to obtain the contractor channel markups for a particular state.

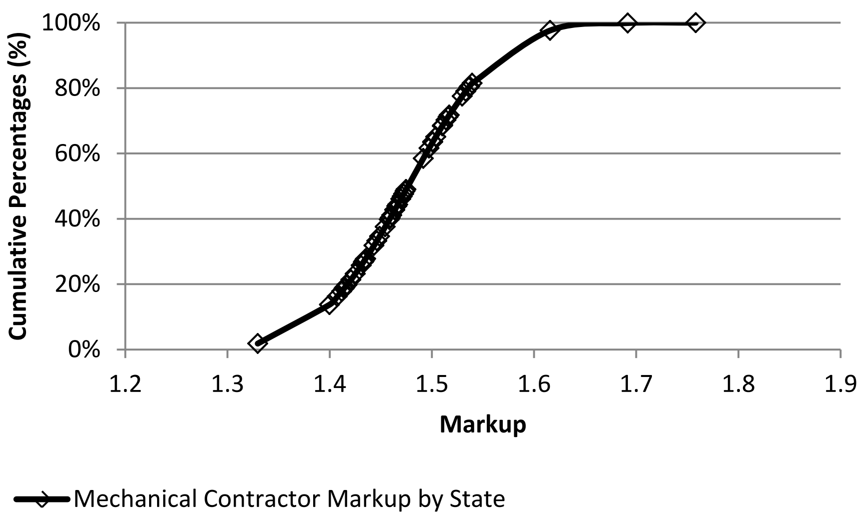

Figure 6.5.1 Cumulative Distribution of Mechanical Contractor Markups for Commercial Refrigeration Equipment

6.6 ESTIMATION OF NATIONAL ACCOUNT MARKUPS

Large customers of commercial refrigeration equipment use national accounts to circumvent the wholesaler channel, thereby 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 but gains in terms of negotiating agreed-upon sales volumes with the customer.

To capture the price savings realized from equipment purchased through national accounts, DOE derived a national account markup, assuming that the resulting equipment price increase was one half of that realized from distribution through the wholesaler channel. In other words, if the price markup resulting from the wholesaler markups is $100, the national account markup is $50. DOE based the use of a national account markup that is one half of that realized from the wholesaler distribution channel on the assumption that the resulting national account equipment price must fall somewhere between the manufacturer selling price and the customer price under the wholesaler distribution channel. Because DOE does not have data suggesting typical values for the actual national account markup, it chose a value halfway between the MSP and the wholesaler markup.

For example, using a baseline MSP of $1,000 for a piece of commercial refrigeration equipment delivered to a supermarket, and a baseline wholesaler markups of 1.357, the resulting baseline customer equipment price for sales through a wholesaler (without sales taxes) is $1,357 ($1,000 × 1.357). The dollar value increase due to the above distribution channel markups is $357 ($1,357 - $1,000). Under the assumption that national account customers realize equipment price increases equal to one half of that through the wholesale distribution channel, the dollar value of the equipment price increase under the national account is $178. The resulting equipment price is $1,178 ($178 + $1,000), which results in national account baseline markup of approximately 1.178 ($1,196 ÷ $1,000). A similar calculation using a value of 1.103 for the wholesaler incremental markup, results in a national account incremental markup of 1.052 ($1,052 ÷ $1,000).

6.7 SALES TAX

Sales tax represents state and local sales taxes that are applied to the customer price of commercial refrigeration equipment. 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, shown in Table 6.7.1. The state-level combined tax rates can be applied to the estimated value of state-level commercial refrigeration equipment shipments 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 9.5 percent with a mean value of 6.2 percent. DOE calculated the weighted-average national-level sales tax rate by multiplying the relative population of each state by the tax rates in Table 6.7.1. The weighted national average sales tax rate was found to be 7.1 percent. The sales tax was applied in the LCC analysis (TSD chapter 8), according to the state in which the equipment was installed.

Table 6.7.1 State Sales Tax Rates

State	Combined State and Local Tax Rate	State	Combined State and Local Tax Rate	State	Combined State and Local Tax Rate
Alabama	8.55%	Kentucky	6.00%	North Dakota	5.95%
Alaska	1.35%	Louisiana	8.75%	Ohio	6.80%
Arizona	7.20%	Maine	5.00%	Oklahoma	8.40%
Arkansas	8.90%	Maryland	6.00%	Oregon	0.00%
California	8.45%	Massachusetts	6.25%	Pennsylvania	6.40%
Colorado	6.10%	Michigan	6.00%	Rhode Island	7.00%
Connecticut	6.35%	Minnesota	7.20%	South Carolina	7.20%
Delaware	0.00%	Mississippi	7.00%	South Dakota	5.40%
Dist. of Columbia	6.00%	Missouri	7.45%	Tennessee	9.45%
Florida	6.65%	Montana	0.00%	Texas	7.95%
Georgia	7.10%	Nebraska	6.00%	Utah	6.70%
Hawaii	4.40%	Nevada	7.85%	Vermont	6.05%
Idaho	6.05%	New Hampshire	0.00%	Virginia	5.60%
Illinois	8.05%	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	7.85%	North Carolina	6.90%	Wyoming	5.50%

Source: The Sale Tax Clearinghouse, http://www.thestc.com/STrates.stm. Last accessed July 10, 2013.

6.8 MARKUPS RESULTS

Table 6.8.1 presents the baseline markup values for each distribution channel and the weighted-average baseline markup values for display cases and for solid-door cases. Table 6.8.2 presents the incremental markup values for each distribution channel and the weighted-average incremental markup values for display cases and for solid-door cases. The mechanical contractor channel markup values presented in both the tables are the national average values.

Table 6.8.1 Baseline Markups by Distribution Channel and Overall Weighted Average Markup

	Wholesaler Channel	Contractor Channel (includes wholesaler markup)*	National Account Channel	Weighted-Average Markup*	
				Display Cases	Solid-Door Equipment
Markup	1.357	2.001	1.178	1.329	1.368

*National average value.

Table 6.8.2 Incremental Markups by Distribution Channel and Overall Weighted Average Markup

	Wholesaler Channel	Contractor Channel (includes wholesaler markup)*	National Account Channel	Weighted-Average Markup*	
				Display Cases	Solid-Door Equipment
Markup	1.103	1.307	1.052	1.098	1.108

*National average value.

DOE used the weighted-average markups to estimate the customer price, before sales tax, of baseline and higher efficiency equipment. For example, if the MSP of a baseline solid-door unit is $1,000, the customer purchase price before sales tax for this baseline equipment is obtained by multiplying the MSP by the weighted-average markup value of 1.368 to obtain the baseline customer purchase price, before sales tax, of $1,368. If the increment in the MSP of the equipment at a higher efficiency level is $100, then the customer purchase price increment, before sales tax, of this equipment can be obtained by multiplying by the weighted-average incremental markup of 1.108 to obtain a customer purchase price increment, before sales tax, of $110.80. The customer purchase price of this higher efficiency equipment before sales tax is the sum of the baseline price and the increment, which is equal to $1,478.80 ($1,368 + $110.80). Even though the example calculation has been shown with the national average values for the contractor channel markups included in the weighted-average markup, the calculations in the LCC analysis (TSD chapter 8) were performed by using the state-wise contractor channel markup values. Finally, the sales tax is applied to the customer purchase price, based on the state in which the equipment is installed, to obtain the final customer purchase price.

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APPENDIX 6A. DATA FOR EQUIPMENT PRICE MARKUPS

6A.1 INTRODUCTION

This appendix provides further details on information presented in chapter 6.

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 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 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	73.7%	Not applicable
Gross Margin	26.3%	
Payroll Expenses	15.1%	Baseline
Executive Salaries & Bonuses	1.7%	
Branch Manager Salaries and Commissions	1.5%	
Sales Executive Salaries & Commissions	0.5%	
Outside Sales Salaries & Commissions	2.1%	
Inside/Counter Sales/Wages	2.8%	
Purchasing Salaries/Wages	0.4%	
Credit Salaries/Wages	0.2%	
IT Salaries/Wages	0.1%	
Warehouse Salaries/Wages	1.4%	
Accounting	0.5%	
Delivery Salaries/Wages	0.7%	
All Other Salaries/Wages & Bonuses	0.8%	
Payroll Taxes	1.0%	
Group Insurance	1.1%	
Benefit Plans	0.3%	
Occupancy Expenses	3.6%	Baseline
Utilities: Heat, Light, Power, Water	0.4%	
Telephone	0.3%	
Building Repairs & Maintenance	0.2%	
Rent or Ownership in Real Estate	2.7%	
Other Operating Expenses	5.5%	Baseline & Incremental
Sales Expenses (incl. Advertising & Promotion)	0.9%	
Insurance (business liability & casualty)	0.2%	
Depreciation	0.4%	
Vehicle Expenses	1.4%	
Personal Property Taxes/Licenses	0.1%	
Collection Exp (collection, credit card fees)	0.3%	
Bad Debt Losses	0.2%	
Data processing	0.3%	
All Other Operating Expenses	1.7%	-

Table 6A.2.1 (cont)*

Item	Percent of Revenue	Scaling
Total Operating Expenses	24.2%	-
Operating Profit	2.1%	Baseline & Incremental
Other Income	0.4%	
Interest Expense	0.5%	
Other Non-operating Expenses	0.0%	
Profit Before Taxes	2.0%	-

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.

6A.3 DETAILED MECHANICAL CONTRACTOR DATA

Chapter 6 presents mechanical contractor revenues and costs in aggregated form, based on U.S. Census Bureau data. Table 6A.3.1 shows the complete breakdown of costs and expenses provided by the U.S. Census Bureau. 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 incremental markups. As described in chapter 6, only those expenses that scale with incremental costs are marked up when there is an incremental change in equipment costs.

Table 6A.3.1 Mechanical Contractor Expenses and Markups*

Item	Dollar Value	Percentage	Scaling
Total Cost of Equipment Sales	$107,144,428	67.80%	Baseline
Cost of materials, components, and supplies	$59,023,964	37.35%	
Payroll, construction workers	$31,373,558	19.85%	
Cost of construction work subcontracted out to others	13,646,192	8.64%	
Cost of selected power, fuels, and lubricants	$3,100,714	1.96%	
Gross Margin	$50,895,129	32.20%	-
Payroll Expenses	$27,626,376	17.48%	Baseline
Fringe benefits, all employees	$13,585,040	8.60%	
Payroll, other employees	$14,041,336	8.89%	
Occupancy Expenses			Baseline
Rental cost for machinery, equipment, and buildings; Cost of repairs to machinery and equipment; Purchased communication services	$3,436,208	2.17%	Baseline
Other Operating Expenses	$6,165,776	3.90%	Baseline & Incremental
Depreciation charges during year	$2,297,550	1.50%	
Computers; Insurance and other business services; Advertising and promotions; Taxes and license fees	$3,868,226	2.40%	
Net Profit Before Income Taxes	$13,666,769	8.60%	Baseline & Incremental

Source: U.S. Census Bureau. *2007 Economic Census, Release Date: 8/14/2009, Sector 23: EC0723I1: Construction: Industry Series: Preliminary Detailed Statistics for Establishments: 2007*. (Last accessed, March 8, 2011.)
<http://factfinder.census.gov/servlet/IBQTable?_bm=y&-geo_id=&-ds_name=EC0723I1&-_lang=en>
*Mechanical contractor costs and expenses are first presented as *total dollar* values and then converted to *percentage* values. This is in contrast to *per dollar of sales revenue* values shown in chapter 6.

6A.4 ESTIMATION OF WHOLESALER AND MECHANICAL CONTRACTOR MARKUP STANDARD DEVIATIONS

The U.S. Department of Energy (DOE) used the U.S. Census Bureau's Economic Census data to estimate commercial refrigeration equipment wholesaler and mechanical contractor markup distributions. In the case of wholesalers, 2007 Economic Census data were available only at the national level. In the case of mechanical contractors, the 2007 census data included state-level plumbing, heating, and air conditioning data for total value of work, number of firms, cost of goods sold, cost of subcontract work, cost of materials, and construction payroll, as shown in Table 6A.4.1. The most recent census was performed in 2007.

DOE used the state-by-state variation in heating, ventilating, and air conditioning (HVAC) contractor markups as a component of state-by-state variation in the life-cycle cost (LCC) analysis. In the case of the contractor markups, the variation in contractor markup by state is captured explicitly in the subsequent LCC analysis. By "selecting" a state during the Monte Carlo analysis, DOE varied the installation costs. Looking at contractor markups on a relative basis, the lowest state is 90 percent of the average markup while the highest state is 119 percent of the average. Using population as a weighting factor, HVAC was combined with other factors that vary by state to create one of the key sets of cost components varied during the analysis.

Table 6A.4.1 Mechanical Contractor Baseline Markups by State, 2007*

State	Number of Firms	Value of Construction ($000)	Cost of Subcontract Work ($000)	Cost of Materials ($000)	Construction Payroll ($000)	Baseline Markup
Alabama	1,425	2,010,305	113,782	876,341	411,100	1.435
Alaska	229	583,171	52,245	171,575	120,909	1.692
Arizona	1,510	3,522,116	179,103	1,508,903	638,469	1.514
Arkansas	1,045	1,065,754	68,417	461,924	213,054	1.434
California	7,272	16,726,969	1,070,065	6,330,469	3,464,667	1.539
Colorado	2,015	3,056,988	261,734	1,195,057	627,663	1.467
Connecticut	1,321	1,704,668	145,740	628,720	361,411	1.501
Delaware	306	481,900	D	D	163,343	1.421
District of Columbia	22	34,600	D	D	50,439	1.458
Florida	5,069	9,061,426	783,859	3,736,811	1,733,721	1.449
Georgia	2,534	4,700,799	365,010	2,224,110	740,722	1.412
Hawaii	280	800,221	46,753	270,723	137,646	1.758
Idaho	594	900,698	62,252	387,181	167,732	1.459
Illinois	3,848	7,641,642	602,251	2,833,489	1,622,307	1.511
Indiana	1,867	4,002,323	431,558	1,319,523	854,157	1.536
Iowa	1,066	1,868,483	144,869	801,239	359,775	1.431
Kansas	966	1,395,359	106,307	580,764	279,636	1.443
Kentucky	1,219	1,747,925	128,902	674,500	353,958	1.510
Louisiana	1,469	1,997,044	162,063	776,784	378,582	1.516
Maine	458	580,816	46,692	234,993	113,162	1.471
Maryland	2,024	5,329,135	698,381	2,009,957	1,031,222	1.425
Massachusetts	2,520	4,099,301	488,098	1,475,525	817,754	1.474
Michigan	3,051	4,420,638	604,850	1,569,113	841,985	1.466
Minnesota	1,635	3,402,921	386,669	1,230,126	698,535	1.470
Mississippi	655	1,025,452	76,709	449,851	189,011	1.433
Missouri	1,816	3,335,124	345,285	1,319,142	689,171	1.417
Montana	432	483,578	42,988	216,792	85,678	1.400
Nebraska	683	1,004,296	94,170	455,264	205,904	1.330
Nevada	498	2,327,842	121,091	988,605	490,859	1.454
New Hampshire	531	620,761	39,784	D	128,512	1.472
New Jersey	3,551	5,062,336	496,174	1,825,407	1,015,432	1.517
New Mexico	599	891,914	67,987	356,961	170,711	1.497

Table 6A.4.1 (cont)*

New York	5,750	10,364,779	1,219,468	3,568,182	1,972,687	1.533
North Carolina	2,978	5,111,396	341,129	2,288,841	1,001,832	1.407
North Dakota	272	360,683	36,037	148,617	70,403	1.414
Ohio	3,514	5,618,591	568,837	2,115,568	1,125,401	1.475
Oklahoma	1,158	1,352,943	94,153	581,079	249,032	1.464
Oregon	1,031	1,893,678	124,070	701,468	412,418	1.530
Pennsylvania	3,653	6,487,476	579,901	2,628,602	1,370,864	1.417
Rhode Island	397	631,202	56,234	229,692	124,727	1.537
South Carolina	1,472	1,991,303	126,123	847,690	352,877	1.501
South Dakota	337	386,186	11,037	158,375	69,605	1.616
Tennessee	1,370	2,595,613	189,293	1,159,952	484,997	1.415
Texas	5,653	10,810,308	823,920	4,605,624	2,102,520	1.435
Utah	892	1,746,398	146,052	769,140	319,812	1.414
Vermont	282	294,806	21,021	D	63,015	1.472
Virginia	2,547	4,623,151	347,055	1,791,740	960,534	1.492
Washington	1,602	4,111,543	370,741	1,546,819	816,533	1.504
West Virginia	416	655,100	D	D	90,660	1.464
Wisconsin	1,839	2,926,545	234,962	1,125,779	662,893	1.446
Wyoming	262	289,391	14,391	128,922	54,792	1.461
Average Baseline Markup						1.477
Standard Deviation						0.070
Relative Standard Deviation						0.048

Source: U.S. Census Bureau. *2007 Economic Census, Release Date: 11/24/2009, Sector 23: EC0723A1: Construction: Geographic Area Series: Detailed Statistics for Establishments: 2007*. (Last accessed May 28, 2010.) <http://factfinder.census.gov/servlet/IBQTable?_bm=y&-ds_name=EC0723A1&-NAICS2007=238220&-_lang=en>

*The Census Bureau withheld data for some states due to sample sizes and the size of errors relative to means. For states where a D appears under the headings for Subcontractor Costs, Materials & Supplies, or Construction Payroll, data was withheld. States missing one or more variables were set equal to an average of neighboring states' baseline markup.

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CHAPTER 7. ENERGY USE ANALYSIS

7.1 INTRODUCTION

An energy use analysis is generally carried out for appliance standards rulemakings to calculate the energy consumption of the equipment in question. For commercial refrigeration equipment, the U.S. Department of Energy (DOE) calculated the energy consumption of the equipment as part of the engineering analysis (see technical support document (TSD) chapter 5) using an energy consumption model. During the analysis for the 2009 final rule for commercial refrigeration equipment (74 FR 1092 (Jan. 9, 2009)), DOE conducted an energy use analysis for certain remote condensing equipment and concluded that the results agreed reasonably well with those calculated by the energy consumption model used in the engineering analysis. Even though self-contained and remote condensing equipment differ with respect to their compressor and condenser configurations, the equipment load calculations, which include conduction, radiation and infiltration loads, and loads from the electrical components, are similar for both types of equipment. Therefore, for the current rulemaking, DOE retained the 2009 final rule analysis conclusions and used the engineering analysis energy consumption model calculations of equipment energy consumption values for life-cycle cost and payback period analysis (TSD chapter 8) and national impact analysis (TSD chapter 10). DOE did not carry out a separate energy use analysis for this rulemaking.

CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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8.1 INTRODUCTION

This chapter describes the analysis the U.S. Department of Energy (DOE) has carried out to evaluate the economic impacts of amended energy conservation standards developed for commercial refrigeration equipment on individual commercial customers, henceforth referred to as *customers*. The effect of standards on customers includes a change in operating cost (usually decreased) and a change in purchase cost (usually increased). This chapter describes two metrics used to determine the effect of standards on customers:

- **Life-cycle cost (LCC)**. The total customer cost over the life of the equipment is the sum of installed cost (purchase and installation costs) and operating costs (maintenance, repair, and energy costs). Future operating costs are discounted to the time of purchase and summed over the lifetime of equipment.
- **Payback period (PBP)**. Payback period is the estimated amount of time it would take customers to recover the higher purchase price of more efficient equipment through lower operating costs.

An efficiency improvement to commercial refrigeration equipment that is financially attractive to a customer will typically have a low PBP and a low LCC associated with it.

This chapter is organized as follows. The remainder of this section outlines the general approach and provides an overview of the inputs to the LCC and PBP analysis of commercial refrigeration equipment. Inputs to the LCC and PBP analysis are discussed in detail in sections 8.2 and 8.3. Results for the LCC and PBP analysis are presented in sections 8.4 and 8.5.

The calculations discussed in this chapter were performed with a series of Microsoft Excel spreadsheets, which are available at www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/52. Instructions for using the spreadsheets are included in appendix 8A of this technical support document (TSD). Detailed results are presented in appendix 8B.

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

This section summarizes DOE's approach to the LCC and PBP analysis for commercial refrigeration equipment.

As part of the engineering analysis (TSD chapter 5), design option levels were ordered on the basis of increasing efficiency (decreased energy consumption) and increasing manufacturer selling price (MSP) values. The order was determined based on the cost-effectiveness of each design option; that is, the ratio of incremental cost increase to incremental energy savings. For the LCC and PBP analysis, DOE chose a maximum of eight levels, henceforth referred to as *efficiency levels*, from the list of engineering design option levels. For those equipment classes for which fewer than eight design option levels were defined in the engineering analysis, each design option level was assigned a corresponding efficiency level. However, for equipment classes where more than eight design option levels were defined, DOE selected specific levels to analyze based on three criteria:

1. The lowest and highest energy consumption levels provided in the engineering analysis were preserved.
2. If the difference in reported energy consumptions and reported manufacturer price between sequential levels was small, only the design option level with the lower amount of energy consumption was selected to be an efficiency level.
3. If the energy consumption savings benefit relative to the increased cost was similar across multiple, sequential design option levels, intermediate design option levels were removed.

The first efficiency level or baseline efficiency level (Level 1) in each equipment class represents the least efficient and the least expensive equipment in that equipment class. The higher efficiency levels (Level 2 and up) have a progressive increase in efficiency and cost from Level 1. The highest efficiency level in each equipment class corresponds to the max-tech level (see TSD chapter 5 for details). DOE treats each efficiency level as a *candidate standard level* (CSL), as each efficiency level represents a potential standard level. The words "efficiency level" and "CSL" can be used interchangeably.

The installed cost of equipment to a customer is the sum of the equipment purchase price and installation costs. The purchase price includes manufacturer production cost, to which a manufacturer markup and outbound freight costs are applied to obtain the MSP. This value is calculated as part of the engineering analysis (TSD chapter 5). DOE then applies additional markups to the equipment to account for the markups associated with the distribution channels for this type of equipment (TSD chapter 6). Installation costs vary by state, depending on the prevailing labor rates.

Operating costs for commercial refrigeration equipment are a sum of maintenance costs, repair costs, and energy costs. These costs are incurred over the life of the equipment and therefore are discounted to the base year (2017, which is the compliance date of the amended standards that will be established as part of this rulemaking). The sum of the installed cost and the operating cost, discounted to reflect the present value, is termed the life-cycle cost or LCC.

Generally, customers incur higher installed costs when they purchase higher efficiency equipment, and these cost increments will be offset partially or wholly by savings in the operating costs over the lifetime of the equipment. Usually, the savings in operating costs are due to savings in energy costs because higher efficiency equipment uses less energy over the lifetime of the equipment. LCC savings are calculated for each CSL of each equipment class.

The PBP of a CSL is obtained by dividing the increase in the installed cost (from the baseline efficiency level) by the decrease in annual operating cost (from the baseline efficiency level). For this calculation, DOE uses the first year operating cost changes as the estimate of the decrease in operating cost, noting that some of the repair and replacement costs used herein are annualized estimates of costs. PBP is calculated for each CSL of each equipment class.

Apart from MSP, installation costs, and maintenance and repair costs, other important inputs for the LCC analysis are markups and sales tax, equipment energy consumption, electricity prices and future price trends, equipment lifetime, and discount rates.

Many inputs for the LCC analysis are estimated from the best available data in the market, and in some cases the inputs are generally accepted representative values within the commercial refrigeration equipment industry. However, in most cases each input has a range of values. For example, even though the average (and representative) lifetime of commercial refrigeration units in certain equipment classes may be 10 years, in general, equipment lifetimes of a typical refrigerator belonging to that equipment class may vary from 5 years to 15 years. While calculations based on the representative values yield average or representative values for the outputs (such as LCC or PBP), such values do not give an estimate of the ranges of values that these outputs could lie in. Therefore, DOE performed the LCC analysis in the form of Monte Carlo simulations in which certain inputs are provided a range of values and probability distributions. The results of the LCC analysis are presented in the form of mean and median LCC savings; percentages of customers experiencing net savings, net cost, and no impact in LCC; and median PBP. For each equipment class, 10,000 Monte Carlo simulations were carried out. The simulations were conducted using Microsoft Excel and Crystal Ball, a commercially available Excel add-in for carrying out Monte Carlo simulations.

Usually, the equipment available in the market will have a distribution of efficiencies; that is, each CSL within an equipment class will have a corresponding market share associated with it. Usually, within an equipment class, the market share of the baseline efficiency level is the highest, and the market share values decrease with an increase in CSL. LCC savings and PBP are calculated by comparing the installed costs and LCC values of the standards-case scenarios against those of the base-case scenario. The base-case scenario is the scenario in which equipment is assumed to be purchased by customers in the absence of the proposed amended energy conservation standards. Standards-case scenarios are scenarios in which equipment is assumed to be purchased by customers after the amended energy conservation standards go into effect. The number of standards-case scenarios for an equipment class is equal to one less than the total number of efficiency levels in that equipment class because each CSL above the baseline efficiency level represents a potential new standard. For the standards-case scenario at a particular CSL, the market share of the efficiency levels were obtained using a roll-up scenario, in which market shares of the efficiency levels (in the base-case scenario) below the corresponding CSL were rolled-up into the CSL. For the base-case scenario in the LCC analysis, DOE calculated the market shares of the efficiency levels using a method described in TSD chapter 10.

Recognizing that each commercial building that uses the commercial refrigeration equipment is unique, DOE analyzed the LCC and PBP calculations for seven types of businesses: (1) supermarkets; (2) wholesaler/retailer multi-line stores, such as “big-box stores,” “warehouses,” and “supercenters;” (3) convenience and small specialty stores, such as meat markets, wine, beer, and liquor stores; (4) convenience stores associated with gasoline stations; (5) full service restaurants; (6) limited service restaurants; and (7) other foodservice businesses, such as caterers and cafeterias. Different types of businesses face different energy prices and also exhibit differing discount rates that they apply to purchase decisions.

Equipment lifetime is another input that does not justify usage of a single value for each equipment class. Therefore, DOE assumes a distribution of equipment lifetimes that are defined by Weibull survival functions.

Another important factor influencing the LCC analysis is the state (location) in which the commercial refrigeration equipment is installed. Inputs that vary based on this factor include energy prices, installation costs, contractor markups, and sales tax. At the national level, the spreadsheets explicitly modeled variability in the model inputs for electricity price and markups using probability distributions based on the relative shipments of units to different states and business types.

Appendix 8C presents additional discussion about the uncertainty and variability in inputs and the advantages of Monte Carlo simulations.

8.1.2 Overview of Life-Cycle Cost and Payback Period Inputs

Inputs to the LCC analysis are categorized as follows: (1) inputs for establishing the total installed cost; and (2) inputs for calculating the operating cost.

The primary inputs for establishing the total installed cost are as follows:

- *Baseline MSP* is the MSP of equipment meeting the baseline efficiency level.
- *Price trends (experiential learning):* A method of adjusting the MSP over time to account for increasing cost efficiency in the production of commercial refrigeration equipment. DOE assumed that, with time and experience, the real cost of producing equipment will decrease marginally
- *CSL MSP increase* is the difference in MSP of a CSL and the baseline MSP.
- *Markups and sales tax* are the markups and sales tax associated with converting the MSP to a customer purchase price (see TSD chapter 6).
- *Installation cost* is the cost to the customer of installing the equipment. It includes cost of labor, overhead, and miscellaneous materials and parts.

The primary inputs for calculating the operating costs are as follows:

- *Equipment energy consumption*: Consumption is the total daily energy consumption of the commercial refrigeration equipment. This value is calculated as part of the engineering analysis (TSD chapter 5) for each design option level in each equipment class.
- *Electricity prices*: Electricity prices used in the analysis are the price per kilowatt-hour paid by each customer for electricity. Electricity prices are determined using average commercial electricity prices in each state, as determined from the Energy Information Administration (EIA) data for 2012. The 2012 average commercial prices derived were modified to reflect the fact that the seven types of businesses analyzed pay electricity prices that are different from the average commercial prices.
- *Electricity price trends*: The EIA's *Annual Energy Outlook 2013*[1] *(AEO2013)* is used to forecast future electricity prices. For the results presented in this chapter, DOE used the regional prices from the *AEO2013* Reference Case to forecast future electricity prices.
- *Maintenance costs:* The labor and materials costs associated with maintaining the operation of the equipment.

- *Repair costs*: The labor and materials costs associated with repairing or replacing components that have failed.
- *Equipment lifetime*: The age at which the commercial refrigeration equipment is retired from service.
- *Discount rate*: The rate at which future costs are discounted to establish their present value.

Figure 8.1.1 depicts the relationships between the installed cost and operating cost inputs for the calculation of the LCC and PBP. Table 8.1.1 summarizes the characteristics of the inputs to the LCC and PBP analysis and lists the corresponding reference chapter in the TSD for details on the calculation of the inputs.

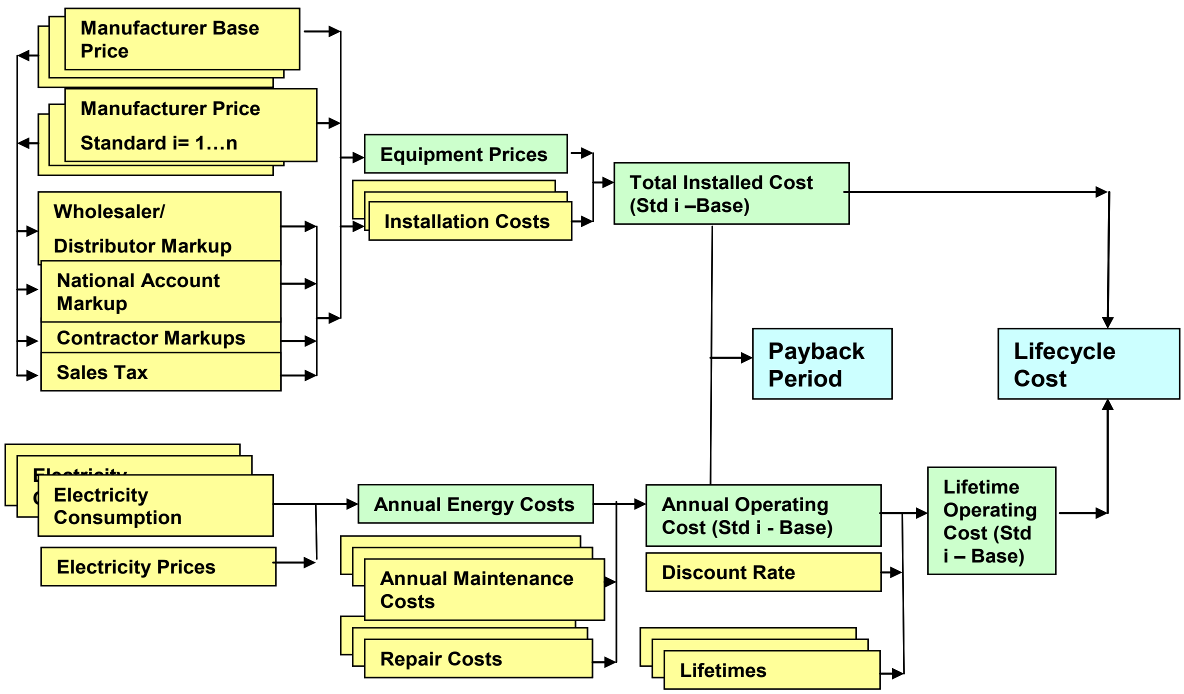


Figure 8.1.1 Flow Diagram of Inputs for the Determination of Life-Cycle Cost and Payback Period

Table 8.1.1 Summary Information of Inputs for the Determination of Life-Cycle Cost and Payback Period

Input	Description	TSD Chapter Reference
Total Installed Cost Primary Inputs		
Baseline MSP	Varies with equipment class.	Chapter 5
Candidate standard level MSP increases	Vary with equipment class and candidate standard level within an equipment class.	Chapter 5
Price trends (experiential learning)	Applies to baseline MSP and MSP increases of all equipment classes	Chapters 8, 10
Markups and sales tax	Markups vary with distribution channel, and sales tax varies with location (state) where equipment is installed.	Chapter 6
Installation price	Varies with location (state) where equipment is installed.	Chapter 8
Operating Cost Primary Inputs		
Equipment energy consumption	Varies with equipment class and candidate standard level within an equipment class.	Chapter 5
Electricity prices	Vary with location, building type.	Chapter 8
Electricity price trends	Vary with location (regional) and price scenario.	Chapter 8
Maintenance costs	Vary with equipment class and candidate standard level within equipment class.	Chapter 8
Repair costs	Vary with equipment class and candidate standard level within equipment class.	Chapter 8
Lifetime	Weibull survival functions. Average values assumed to be 10 years for large grocery store equipment and 15 years for small retail stores for remote condensing equipment. Average values assumed to be 10 years for all self-contained equipment.	Chapters 3, 8
Discount rate	Varies with type of business.	Chapter 8

All of the inputs depicted in Figure 8.1.1 and summarized in Table 8.1.1 are discussed in sections 8.2 and 8.3.

8.1.3 Effect of Current Standards

Standards set by this rulemaking are likely to go into effect in 2017, and the standards set by the 2009 DOE final rule on commercial refrigeration equipment (the January 9, 2009 final rule) went into effect on January 1, 2012. 74 FR at 1092. DOE does not have sufficient data concerning the commercial refrigeration equipment market at the time the notice of proposed rulemaking (NOPR) analyses was conducted. However, DOE assumed that the equipment manufactured before 2017 will be compliant with the January 2009 final rule standards. The general practice in DOE appliance standards rulemakings is to assume that the current technology level of the market will continue to remain at, or very near, the current level until new DOE standards are brought into effect at a future date. The design option levels for each equipment class (TSD chapter 5) were chosen based on technology levels in the commercial refrigeration equipment market at the time of the NOPR analysis (TSD chapter 3). However, the composition of this market will change as a result of the January 2009 final rule standards, which go into effect before 2017, at which time the standards established by the current rulemaking would go into effect. While it is difficult to predict the state of the market in the year 2017, DOE devised a method to estimate the efficiency level of the market baseline in 2017 based on certain assumptions.

DOE assumed that the standards established by the January 2009 final rule will form the lowest efficiency level before the amended standards, established as part of this rulemaking—which will be in effect in 2017. This is a reasonable assumption considering that the 2009 standards are appreciably more stringent than the then-prevailing market baseline and that notable technology improvements are necessary to reach the efficiency levels prescribed by the 2009 final rule. DOE is not in a position to speculate on the other potential improvements of equipment efficiency in the market from the time the 2009 final rule standards go into effect and 2017, aside from assuming compliance with the 2009 final rule standards. As a result, even though the market could potentially continue to improve the efficiency of commercial refrigeration equipment beyond that required by the standards established by the 2009 final rule, DOE assumed that the market will remain in a similar state from the compliance date of the 2009 final rule standards until 2017. To approximate this assumed market efficiency level in 2017 in the current analysis, DOE introduced a new baseline efficiency level—henceforth referred to as the *standards baseline level*—that is set at the same level as the 2009 final rule standard. Any design option levels from the engineering analysis that were less efficient than the corresponding standards baseline level were disregarded for the downstream analyses (LCC analysis and national impact analysis (NIA)); that is, they were not included as efficiency levels (candidate standard levels). Design option levels from the engineering results that were more efficient than the standards baseline level were considered for higher efficiency levels (Level 2, Level 3, and so on). It should be noted that, in general, there is no design option level from the engineering analysis that corresponds specifically to this assumed market baseline (standards baseline). The process of estimating the 2017 market baseline level is explained with the aid of an example in the following paragraph.

Table 8.1.2 shows the 13 design option levels for equipment class VOP.SC.M (self-contained vertical open refrigerator), obtained from the engineering analysis. This table represents the current (2012) technology levels modeled for VOP.SC.M equipment on the market. The energy conservation standard for this class prescribed by the January 2009 final rule is given by the expression $1.74 \times TDA + 4.71$ kilowatt-hours per day (kWh/day), where *TDA* (in ft^2) represents the total display area of the equipment. The *TDA* value for this representative VOP.SC.M unit, which was modeled in the engineering analysis, is 14.93 ft^2. When substituted into the expression, it yields a maximum allowable total daily energy consumption value of 30.69 kWh/day. This value, when compared against the list of design option levels (Table 8.1.2), is between the design option levels 7 and 8 (AD7 and AD8). As explained in the previous paragraph, DOE assumed that when the January 2009 final rule standards go into effect, 30.69 kWh/day would represent the minimum efficiency level of the market for this unit and that it would remain so until 2017. To approximate this state of market technology, DOE assumed the efficiency levels shown in Table 8.1.3 for VOP.SC.M equipment. The first column of Table 8.1.3 represents the efficiency levels for the LCC analysis, and the second column represents the corresponding design option levels. As stated in the preceding paragraph, there is no design option level in the current rulemaking that corresponds directly to the first efficiency level. Instead, this design option level is designated as "SB," which stands for "standards baseline." The total daily energy consumption for Efficiency Level 1 of this unit is equal to 30.69 kWh/day, which is the same as the January 2009 final rule standards level. The MSP corresponding to Efficiency Level 1 was obtained by interpolating the prices between AD7 and AD8 in Table 8.1.2.

Table 8.1.2 Design Option Levels for VOP.SC.M Obtained from Engineering Analysis

Design Option Level	Total Daily Energy Consumption *kWh/day*	Manufacturer Selling Price *2012$*	Design Option Added*
AD1	39.60	$2,439.74	Baseline
AD2	37.91	$2,458.10	High-Eff. Reciprocating Compressor
AD3	34.96	$2,513.31	Enhanced-UA Condenser Coil
AD4	34.35	$2,526.53	Permanent Split Cap. Evap. Fan Motor
AD5	32.81	$2,567.74	Enhanced-UA Evaporator Coil
AD6	32.09	$2,589.03	Brushless DC Evap. Fan Motor
AD7	31.58	$2,604.45	Super T8 Lighting
AD8	30.37	$2,663.18	Night Curtains
AD9	30.03	$2,680.80	Permanent Split Cap. Cond. Fan Motor
AD10	29.60	$2,718.25	Brushless DC Cond. Fan Motor
AD11	26.70	$3,137.04	LED Lighting with Occupancy Sensors
AD12	26.62	$3,180.03	Additional ½-inch Insulation
AD13	26.46	$4,086.26	Vacuum Insulated Panels

*For information about specific technologies, refer to chapter 5 and appendix 5A.

Table 8.1.3 Efficiency Levels for VOP.SC.M

Efficiency Level for LCC Analysis	Corresponding Design Option Level	Total Daily Energy Consumption *kWh/day*	Manufacturer Selling Price *2012$*
Level 1	SB	30.69	$2,647.69
Level 2	AD8	30.37	$2,663.18
Level 3	AD9	30.03	$2,680.80
Level 4	AD10	29.60	$2,718.25
Level 5	AD11	26.70	$3,137.04
Level 6	AD12	26.62	$3,180.03
Level 7	AD13	26.46	$4,086.26

8.2 LIFE-CYCLE COST INPUTS

8.2.1 Definition

Life-cycle cost is the total customer cost over the life of a piece of equipment, including purchase cost and operating costs (energy costs, maintenance costs, and repair costs). Future operating costs are discounted to the time of purchase and summed over the lifetime of the equipment. Life-cycle cost is defined by the following equation:

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

Eq. 8.1

Where:

LCC = life-cycle cost ($),
IC = total installed cost ($),
N = lifetime of equipment (years),
OC_t = operating cost ($) of the equipment in year t,
r = discount rate, and
t = year for which operating cost is being determined.

DOE expressed all costs in 2012$. Total installed cost, operating cost, lifetime, and discount rate are discussed in the following sections. In the LCC analysis, the first year of equipment purchase is assumed to be 2017.

8.2.2 Total Installed Cost Inputs

The total installed cost to the customer is defined by the following equation:

$$IC = EQP + INST$$

Eq. 8.2

Where:

EQP = customer purchase price for the equipment ($), and
$INST$= installation cost or the customer price to install equipment ($).

The remainder of this section provides information about the inputs DOE used to calculate the total installed cost for commercial refrigeration equipment. Table 8.2.1 shows inputs for the determination of total installed cost.

Table 8.2.1 Inputs for Total Installed Costs

Baseline manufacturer selling price ($)
Candidate standard level manufacturer selling price increases ($)
Experiential Learning coefficient (0.9945)
Wholesaler markup
Mechanical contractor markup
National account markup
Sales tax ($)
Installation cost ($)

8.2.2.1 Baseline Manufacturer Selling Price

The baseline MSP is the price charged by manufacturers for equipment meeting existing minimum efficiency (or baseline) standards. DOE developed MSP values for the 25 primary equipment classes (TSD chapter 5). Table 8.2.2 shows the set of 25 primary equipment classes that DOE evaluated during the current rulemaking.

Table 8.2.2 Equipment Classes Evaluated for LCC Analysis

Description (Equipment Family. Operating Mode. Temperature)	Abbreviation	Current Standards Set By
Vertical Open.Remote Condensing.Medium	VOP.RC.M	January 2009 final rule
Vertical Open.Remote Condensing.Low	VOP.RC.L	January 2009 final rule
Vertical Open.Self-Contained.Medium	VOP.SC.M	January 2009 final rule
Vertical Closed Transparent.Remote Condensing.Medium	VCT.RC.M	January 2009 final rule
Vertical Closed Transparent.Remote Condensing.Low	VCT.RC.L	January 2009 final rule
Vertical Closed Transparent.Self-Contained.Medium	VCT.SC.M	EPCA
Vertical Closed Transparent.Self-Contained.Low	VCT.SC.L	EPCA
Vertical Closed Transparent.Self-Contained.Ice Cream	VCT.SC.I	January 2009 final rule
Vertical Closed Solid.Self-Contained.Medium	VCS.SC.M	EPCA
Vertical Closed Solid.Self-Contained.Low	VCS.SC.L	EPCA
Vertical Closed Solid.Self-Contained.Ice Cream	VCS.SC.I	January 2009 final rule
Semi-Vertical Open.Remote Condensing.Medium	SVO.RC.M	January 2009 final rule
Semi-Vertical Open.Self-Contained.Medium	SVO.SC.M	January 2009 final rule
Service Over Counter.Remote Condensing.Medium	SOC.RC.M	January 2009 final rule
Horizontal Open.Remote Condensing.Medium	HZO.RC.M	January 2009 final rule
Horizontal Open.Remote Condensing.Low	HZO.RC.L	January 2009 final rule
Horizontal Open.Self-Contained.Medium	HZO.SC.M	January 2009 final rule
Horizontal Open.Self-Contained.Low	HZO.SC.L	January 2009 final rule
Horizontal Closed Transparent.Self-Contained.Medium	HCT.SC.M	EPCA
Horizontal Closed Transparent.Self-Contained.Low	HCT.SC.L	EPCA
Horizontal Closed Transparent.Self-Contained.Ice Cream	HCT.SC.I	January 2009 final rule
Horizontal Closed Solid.Self-Contained.Medium	HCS.SC.M	EPCA
Horizontal Closed Solid.Self-Contained.Low	HCS.SC.L	EPCA
Pull-Down.Self-Contained.Medium	PD.SC.M	EPCA
Service Over Counter. Self-Contained. Medium	SOC.SC.M	AEMTCA

Nine primary equipment classes in Table 8.2.2 are subject to standards set by the Energy Policy and Conservation Act (EPCA) as amended by the Energy Policy Act of 2005 (42 U.S.C. 6313(c)(2)–(3)); 15 primary equipment classes are subject to standards set by DOE in the January 9, 2009 final rule (74 FR at 1092), and one primary equipment class is subject to standards set by the American Energy Manufacturing Technical Corrections Act (AEMTCA) (42 U.S.C. 6313(c)(4)). Table 8.2.3 presents the baseline energy consumption values and the baseline MSPs used in the LCC analysis for the representative sizes for each of the 25 primary equipment classes (TSD chapter 5). Table 8.2.3 also identifies whether the baseline was obtained from the engineering analysis or was set at the standards baseline, as explained in section 8.1.3. For some equipment classes, the January 2009 final rule standards, EPCA standards, or AEMTCA standard form the baseline efficiency level, and for the remaining equipment classes, the market baseline (from the engineering analysis) forms the baseline efficiency level because the market baseline for these equipment classes was found to be more efficient than the current standard level.

Table 8.2.3 Baseline Energy Consumption Levels and MSP Values for the Representative Commercial Refrigeration Equipment Units of All 24 Primary Equipment Classes

Equipment Class	Baseline energy consumption *kWh/day*	Manufacturer Selling Price *2012$*	Baseline Type
VOP.RC.M	47.78	5,041.54	Standards Baseline
VOP.RC.L	108.23	5,457.86	Standards Baseline
VOP.SC.M	30.69	2,647.69	Standards Baseline
VCT.RC.M	16.25	6,883.56	Standards Baseline
VCT.RC.L	39.01	7,856.68	Standards Baseline
VCT.SC.M	9.22	2,601.64	Standards Baseline
VCT.SC.L	29.09	3,468.66	Engineering Baseline
VCT.SC.I	20.71	3,826.67	Standards Baseline
VCS.SC.M	4.45	1,694.25	Engineering Baseline
VCS.SC.L	11.00	1,880.11	Engineering Baseline
VCS.SC.I	19.12	2,237.74	Standards Baseline
SVO.RC.M	36.38	4,258.91	Standards Baseline
SVO.SC.M	26.73	2,084.45	Standards Baseline
SOC.RC.M	26.12	7,380.31	Standards Baseline
HZO.RC.M	14.43	4,065.55	Standards Baseline
HZO.RC.L	33.10	4,658.43	Standards Baseline
HZO.SC.M	14.79	1,044.88	Standards Baseline
HZO.SC.L	30.12	1,998.28	Standards Baseline
HCT.SC.M	2.28	836.64	Engineering Baseline
HCT.SC.L	5.17	959.50	Engineering Baseline
HCT.SC.I	3.30	1,035.70	Standards Baseline
HCS.SC.M	0.73	746.26	Engineering Baseline
HCS.SC.L	2.11	762.34	Engineering Baseline
PD.SC.M	6.91	1,473.54	Standards Baseline
SOC.SC.M	31.60	7,980.38	Standards Baseline

8.2.2.2 Candidate Standard Level Energy Consumption and Manufacturer Selling Price Increases

The CSL MSP increase is the change in MSP associated with producing equipment at higher efficiency levels above the baseline. Increases in MSP as a function of equipment efficiency were developed for each of the 25 primary equipment classes (TSD chapter 5). The engineering analysis (TSD chapter 5) established a series of MSP increases for each CSL. Table 8.2.4 presents the increase in MSP values corresponding to all efficiency levels for each equipment class. Table 8.2.5 presents the daily energy consumption of the representative units belonging to each of the 25 primary equipment classes that were selected for the engineering analysis (TSD chapter 5).

Table 8.2.4 CSL MSP Increases (Price Increases Relative to the Price of Baseline Efficiency Level)

Equipment Class	Increase in MSP by Efficiency Level* *2012$*						
	Level 2	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**
VOP.RC.M	$44.98	$167.18	$1,184.95	$1,249.03	$3,906.09	NA	NA
VOP.RC.L	$61.40	$414.00	$485.07	$4,822.00	NA	NA	NA
VOP.SC.M	$15.50	$33.12	$70.56	$489.36	$532.34	$1,438.58	NA
VCT.RC.M	$21.12	$533.52	$662.01	$731.24	$755.52	$3,840.29	NA
VCT.RC.L	$156.41	$284.89	$353.39	$396.62	$4,448.32	NA	NA
VCT.SC.M	$40.95	$259.13	$387.61	$408.90	$454.09	$463.89	$1,553.24
VCT.SC.L	$74.76	$279.92	$296.83	$425.31	$438.53	$505.01	$1,969.64
VCT.SC.I	$74.83	$88.05	$216.53	$237.82	$283.74	$2,225.19	NA
VCS.SC.M	$39.88	$45.68	$49.69	$62.90	$84.19	$129.38	$1,218.74
VCS.SC.L	$46.73	$59.43	$66.91	$112.10	$125.31	$146.60	$1,611.23
VCS.SC.I	$0.46	$20.43	$33.65	$79.57	$100.86	$2,042.31	NA
SVO.RC.M	$9.84	$186.04	$962.82	$1,015.42	$2,719.94	NA	NA
SVO.SC.M	$2.33	$61.07	$86.03	$427.55	$466.72	$1,056.08	NA
SOC.RC.M	$15.20	$43.06	$508.17	$555.49	$702.32	$1,968.09	NA
HZO.RC.M	$1,154.40	NA	NA	NA	NA	NA	NA
HZO.RC.L	$2,056.74	NA	NA	NA	NA	NA	NA
HZO.SC.M	$1.52	$12.17	$53.87	$853.46	NA	NA	NA
HZO.SC.L	$478.71	NA	NA	NA	NA	NA	NA
HCT.SC.M	$3.69	$8.53	$14.41	$97.19	$109.67	$147.84	$654.17
HCT.SC.L	$6.67	$16.51	$99.29	$105.16	$117.64	$155.81	$840.73
HCT.SC.I	$2.11	$14.59	$53.13	$968.18	NA	NA	NA
HCS.SC.M	$1.19	$6.03	$11.91	$24.39	$61.22	$457.10	NA
HCS.SC.L	$1.79	$6.49	$12.36	$24.84	$61.68	$598.89	NA
PD.SC.M	$45.31	$147.79	$154.40	$165.04	$293.53	$341.89	$1,196.02
SOC.SC.M	$90.20	$131.29	$152.58	$617.69	$665.00	$811.84	$2,077.61

* "NA" implies no design options associated with the efficiency level

Table 8.2.5 Energy Consumption Values for Representative Commercial Refrigeration Equipment Units of the 25 Primary Equipment Classes at All Efficiency Levels

Equipment Class	Total Annual Energy Usage* *kWh/day*							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	47.78	46.84	44.33	35.71	35.51	35.06	NA	NA
VOP.RC.L	108.23	106.22	101.03	100.51	98.87	NA	NA	NA
VOP.SC.M	30.69	30.37	30.03	29.60	26.70	26.62	26.46	NA
VCT.RC.M	16.25	15.56	8.10	6.26	6.01	5.97	5.49	NA
VCT.RC.L	39.01	33.27	31.13	30.58	30.29	28.85	NA	NA
VCT.SC.M	9.22	7.56	4.08	3.24	3.13	2.98	2.97	2.68
VCT.SC.L	29.09	21.51	13.48	13.30	12.44	12.37	12.09	11.57
VCT.SC.I	20.71	17.57	17.45	16.51	16.36	16.14	15.37	NA
VCS.SC.M	4.45	2.53	2.36	2.30	2.17	2.01	1.81	1.39
VCS.SC.L	11.00	7.69	7.26	7.07	6.75	6.66	6.56	5.71
VCS.SC.I	19.12	19.09	18.24	18.11	17.79	17.64	16.53	NA
SVO.RC.M	36.38	36.11	33.85	27.71	27.57	27.26	NA	NA
SVO.SC.M	26.73	26.67	25.74	25.36	23.29	23.24	23.12	NA
SOC.RC.M	26.12	25.62	24.97	20.43	20.31	20.15	19.93	NA
HZO.RC.M	14.43	14.17	NA	NA	NA	NA	NA	NA
HZO.RC.L	33.10	32.22	NA	NA	NA	NA	NA	NA
HZO.SC.M	14.79	14.76	14.60	14.49	14.26	NA	NA	NA
HZO.SC.L	30.12	29.91	NA	NA	NA	NA	NA	NA
HCT.SC.M	2.28	2.03	1.87	1.73	0.84	0.75	0.67	0.49
HCT.SC.L	5.17	4.52	4.11	1.83	1.77	1.70	1.57	1.18
HCT.SC.I	3.30	3.22	3.07	2.86	2.13	NA	NA	NA
HCS.SC.M	0.73	0.65	0.60	0.56	0.50	0.42	0.25	NA
HCS.SC.L	2.11	1.88	1.73	1.61	1.46	1.27	0.74	NA
PD.SC.M	6.91	3.90	2.23	2.20	2.16	1.75	1.64	1.42
SOC.SC.M	31.60	28.04	27.04	26.80	22.02	21.88	21.70	21.41

* "NA" implies no design options associated with the efficiency level

8.2.2.3 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 commercial refrigeration equipment manufacturing process over time, DOE used a price forecast methodology based on experiential learning (see appendix 8D for more information on experiential learning). For the LCC model, the impact of experiential learning was a decrease in the MSP to account for changes from the time prices were developed (2012) until the start of the LCC analysis (2017). The experiential learning factor used in the LCC and Payback Period Analysis was 0.9945, which means MSPs shown on Table 8.2.4 were reduced by 0.55 percent in the development of total installed costs.

8.2.2.4 Markups

As discussed in TSD chapter 6, DOE calculated distribution channel markups to determine the equipment purchase price to customers from the equipment MSP. DOE calculated baseline markups to convert baseline MSP to baseline customer purchase price and incremental markups to convert the increments in MSP into increments in customer purchase price. DOE used these markup values in the LCC analysis for calculation of baseline and higher efficiency equipment price to customers.

8.2.2.5 Installation Cost

Most refrigerated display cases are installed in fairly standard configurations, which helps in creating standardized estimates for the cost of installation across all equipment classes. For example, supermarkets commonly configure display cases as part of a "lineup" of similar cases. Horizontal open cases are commonly installed as single units placed in appropriate store locations. Self-contained display cases are used for portable or temporary product displays, or sometimes used as end-caps of aisles.

For remote condensing equipment, typical steps in the installation of display cases in a lineup are as follows:

- move new case to lineup position in store;
- position case in lineup, providing shims for vertical spacing as needed;
- caulk or seal adjacent cases together;
- bolt adjacent cases together;
- trim cases together for good visual look (installing bumpers and covering seams);
- braze refrigerant lines as necessary to system piping (already in place);
- if hot gas defrost is used, braze hot gas defrost refrigerant lines as necessary to defrost piping (already in place);
- provide electrical conduit and tie-in electrical connections to case;
- install display lamps; and
- set refrigerant and defrost control settings.

Note that final operational testing of cases is undertaken after initial installation of all cases in a lineup and refrigerant is piped to each case.

For self-contained refrigeration equipment, typical installation steps are as follows:

- move new equipment to the target position in store;
- where applicable, make sure that the condensate pan is installed properly;
- plug cord into electrical outlet and turn on main power;
- make sure the evaporator and condenser fans are functioning properly;
- where applicable, turn on lights; and
- adjust temperature settings to desired levels.

The installation steps just listed for both self-contained and remote condensing equipment are not influenced by any of the engineering design options accounted for in this rulemaking.

DOE assumes that the night curtains (for open display cases) are provided by the manufacturer in pre-installed condition and hence that no additional costs are incurred for installation of night curtains. From conversations with consultants with experience in retrofitting display cases with light-emitting diode (LED) lighting and occupancy sensors, DOE determined that the additional costs incurred in installation of occupancy sensors are minimal, and it is unlikely that installers would bill additional charges to the customers. Therefore, DOE assumes that the installation costs do not vary with efficiency levels in any equipment class.

The installation costs may vary from one equipment class to another, but they do not vary with efficiency levels within an equipment class. Costs that do not vary with efficiency levels do not impact the LCC, PBP, or NIA results. DOE retained the nationally representative installation cost values from the January 2009 final rule analysis for all remote condensing equipment as $2,000 and for all self-contained equipment as $750, and simply escalated the values from 2007$ to 2012$, resulting in 2012 installation costs of $2,299 and $862, respectively. DOE designed the LCC spreadsheet such that installation costs can be varied by CSL, but DOE has modeled installation cost as constant across CSLs for the NOPR analysis.

Table 8.2.6 shows installation cost indices for installations in each of the 50 states, plus the District of Columbia, which were used to adjust the nationally representative installation costs for each state. To arrive at an average index for each state, DOE first weighted the city indices in each state by their population within the state. DOE used city-level population estimates for 2011 and state-level population weights for 2012 from the U.S. Census Bureau to calculate a weighted-average index for each state.

8.2.2.6 Weighted-Average Total Installed Cost

As presented in Eq. 8.2, the total installed cost is the sum of the equipment price and the installation cost. DOE derived the customer equipment price for any given standard level by multiplying the baseline MSP by the baseline markup and sales tax and adding to it the product of the incremental MSP and the incremental markup and sales tax. Because MSPs, markups, and the sales tax all can take on a variety of values depending on location (state), the resulting total installed cost for a particular CSL will not be a single-point value, but rather a distribution of values.

Table 8.2.6 Installation Cost Indices (National Value = 100.0)

State	Index	State	Index	State	Index
Alabama	56.4	Kentucky	84.8	North Dakota	62.6
Alaska	112.1	Louisiana	64.2	Ohio	99.2
Arizona	83.9	Maine	81.4	Oklahoma	56.0
Arkansas	59.3	Maryland	88.5	Oregon	106.4
California	132.9	Massachusetts	128.4	Pennsylvania	127.4
Colorado	83.5	Michigan	108.1	Rhode Island	119.2
Connecticut	126.2	Minnesota	122.3	South Carolina	38.4
Delaware	125.4	Mississippi	58.2	South Dakota	44.1
Dist. of Columbia	101.5	Missouri	105.8	Tennessee	76.3
Florida	72.2	Montana	78.1	Texas	61.9
Georgia	70.0	Nebraska	83.6	Utah	75.9
Hawaii	121.1	Nevada	106.1	Vermont	76.7
Idaho	74.0	New Hampshire	95.3	Virginia	78.4

Table 8.2.6 (cont)

State	Index	State	Index	State	Index
Illinois	138.6	New Jersey	135.4	Washington	115.0
Indiana	86.3	New Mexico	74.1	West Virginia	92.7
Iowa	84.9	New York	170.6	Wisconsin	103.1
Kansas	73.7	North Carolina	57.9	Wyoming	71.2

The weighted-average costs for the VCT.SC.L equipment class are presented in Table 8.2.7 for the baseline level at national average markup rates and national average installation costs for illustration purposes. Derivation of the total installed cost is straightforward. The baseline MSP and the standard level MSP increases are the starting points for determining the total installed cost (values are taken directly from Table 8.2.4 and Table 8.2.5). DOE used the baseline and incremental markups, the sales tax, and installation costs to convert the MSPs into total installed costs for a case where the incremental installation costs are held flat. Table 8.2.7 summarizes the weighted average or mean costs and markups necessary for determining the weighted-average baseline and standard level total installed costs for convenience stores as an example.

Table 8.2.7 Costs and Markups for Determination of Weighted-Average Total Installed Costs for Convenience Stores (VCT.SC.L)*

Variable	Weighted Average or Mean Value
Baseline MSP	$3,468.66
Standard Level MSP Increase (Efficiency Level 4)	$296.83
Experiential Learning	0.9945
Overall Markup Factor–Baseline	1.4236
Overall Markup Factor–Incremental	1.1761
Installation Cost–Baseline	$862
Installation Cost Factor, for U.S. Average	1

*Installation costs apply to the baseline unit, with no incremental installation costs.

To illustrate the derivation of the weighted-average total installed cost based on the data shown in Table 8.2.7, DOE presents the following calculation for the baseline (Level 1) and for a higher efficiency level (Level 4) VCT.SC.L equipment class. For the baseline product, the calculation of the total installed cost at national average conditions is as follows:[a]

$$IC_{BASE\ VCT.SC.L} = EQP_{BASE\ VCT.SC.L} + INST_{BASE\ VCT.SC.L} \times ISTINDEX$$

$$= MFG_{BASE\ VCT.SC.L} \times MU_{BASE\ VCT.SC.L} \times EL + INST_{BASE\ VCT.SC.L} \times ISTINDEX$$

= \$3,468.66 × (1.4236) × 0.9945 + \$862 x (1.00)

= \$4,911 + \$862

= \$5,773

Eq. 8.3

[a] Note that the numbers shown in Eq. 8.3 have been rounded and do not exactly match the numbers in the analysis.

Where:

$IC_{BASE\ VCT.SC.L}$ = total installed cost of VCT.SC.L equipment at baseline efficiency level ($),
$EQP_{BASE\ VCT.SC.L}$ = equipment purchase price of VCT.SC.L equipment at baseline efficiency level ($),
EL = experiential learning factor applied to all MSP baseline and incremental values,
$INST_{BASE\ VCT.SC.L}$ = installation cost of VCT.SC.L equipment at baseline efficiency level ($),
$MFG_{BASE\ VCT.SC.L}$ = MSP of VCT.SC.L equipment at baseline efficiency level ($),
$MU_{BASE\ VCT.SC.L}$ = overall baseline markup for equipment class VCT.SC.L, and
$ISTINDEX$ = location-dependent multiplier on installation costs; approximately 1.0 at a national average.

The calculation of the higher Efficiency Level 4 total installed cost includes the use of an MSP increment. DOE uses an incremental markup factor that applies to incremental increases in MSP. The Level 4 price is equal to the baseline price calculated in Eq. 8.3, plus the MSP increment for a higher efficiency level multiplied by the incremental markup.

As an example, DOE calculated the national average Level 4 total installed cost ($IC_{VCT,SC,L\ LEVEL4}$) as follows:[b]

$$IC_{VCT.SC.L\ LEVEL4} = EQP_{VCT.SC.L\ LEVEL4} + INST_{VCT.SC.L\ LEVEL4} \times ISTINDEX$$

$$= MFG_{BASE\ VCT.SC.L} \times MU_{BASE\ VCT.SC.L} + \Delta MFG_{VCT.SC.L\ LEVEL4} \times MU_{VCT.SC.L\ LEVEL4} + INST_{VCT.SC.L\ LEVEL4} \times ISTINDEX$$

$$= \$3{,}468.66 \times (1.4236) \times 0.9945 + \$296.83 \times (1.1761) \times 0.9945 + \$862 \times (1.000)$$

$$= \$6{,}120$$

Eq. 8.4

Where:

$IC_{VCT.SC.L\ LEVEL4}$ = total installed cost of VCT.SC.L equipment at Efficiency Level 4 ($),
$EQP_{VCT.SC.L\ LEVEL4}$ = equipment price of VCT.SC.L equipment at Efficiency Level 4 ($),
$INST_{VCT.SC.L\ LEVEL4}$ = installation cost of VCT.SC.L equipment at Efficiency Level 4 ($),
$\Delta MFG_{VCT.SC.L\ LEVEL4}$ = incremental increase in MSP of VCT.SC.L equipment at Efficiency Level 4 compared to equipment at baseline efficiency level ($), and
$MU_{VCT.SC.L\ LEVEL4}$ = incremental markup for equipment class VCT.SC.L.

Table 8.2.8 presents the weighted-average equipment price, installation costs, and total installed costs for the VCT.SC.L equipment classes at the baseline level and each higher efficiency level examined.

[b] Note that the numbers shown in Eq. 8.4 have been rounded and do not exactly match the numbers in the analysis.

Table 8.2.8 Weighted-Average Equipment Price, Installation Cost, and Total Installed Costs for VCT.SC.L at U.S. Average Conditions (2012$)[c]

Efficiency Level	Equipment Price (MSP)	Installation Cost	Total Installed Cost
1 (Baseline)	$3,468.66	$862	$5,773
2	$3,543.43	$862	$5,860
3	$3,748.59	$862	$6,100
4	$3,765.49	$862	$6,120
5	$3,893.98	$862	$6,270
6	$3,907.19	$862	$6,286
7	$3,973.68	$862	$6,363
8	$5,438.31	$862	$8,077

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:

$$OC = EC + RC + MC$$

Eq. 8.5

Where:

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

The remainder of this section provides information about the variables that DOE used to calculate the operating cost for commercial refrigeration equipment. Table 8.2.9 shows the inputs for the determination of operating costs.

Table 8.2.9 Inputs for Operating Costs

Electricity price (cents/kWh)
Electricity price trend
Repair cost ($)
Maintenance cost ($)
Lifetime (years)
Discount rate (%)
Effective date of standard
Baseline electricity consumption (kWh/day)
Standard case electricity consumption (kWh/day)

[c] Figures shown in the table are rounded and do not match values in the analysis. In the LCC model, none of the numbers in this series of calculations are rounded so total installed cost in the analysis differs from values on this table.

8.2.3.1 Electricity Price Analysis

This section describes the electricity price analysis used to develop the energy portion of the annual operating costs for commercial refrigeration equipment used in different commercial building types.

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. Table 8.2.10 provides data on the adjusted electricity prices.

Table 8.2.10 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	10.58	Kentucky	8.66	North Dakota	7.98
Alaska	14.79	Louisiana	7.79	Ohio	9.47
Arizona	9.54	Maine	11.58	Oklahoma	7.26
Arkansas	7.68	Maryland	10.52	Oregon	8.34
California	13.60	Massachusetts	13.97	Pennsylvania	9.37
Colorado	9.34	Michigan	10.95	Rhode Island	12.04
Connecticut	14.70	Minnesota	8.86	South Carolina	9.57
Delaware	10.11	Mississippi	9.28	South Dakota	8.01
Dist. of Col.	12.00	Missouri	8.16	Tennessee	10.29
Florida	9.76	Montana	9.16	Texas	8.17
Georgia	9.47	Nebraska	8.40	Utah	8.05
Hawaii	34.83	Nevada	8.86	Vermont	14.30
Idaho	6.83	New Hampshire	13.40	Virginia	8.11
Illinois	8.19	New Jersey	12.83	Washington	7.67
Indiana	9.07	New Mexico	9.30	West Virginia	8.42
Iowa	8.00	New York	15.08	Wisconsin	10.54
Kansas	9.13	North Carolina	8.61	Wyoming	8.23

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. Eq. 8.6 shows the ratios of prices paid by the seven 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. 8.6

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.

Table 8.2.11 shows the derivation of the EPRICE ratios from CBECS.

Table 8.2.11 Derived Average Commercial Electricity Price by Business Type

Business Type	Electricity Price *cents/kWh*	Ratio of Electricity Price to Average Price for all Commercial Buildings
Grocery store/food market	0.07222	0.910
Convenience store *	0.08583	1.082
Convenience store with gas station	0.07722	0.973
Multi-line retail **	0.07262	0.915
Limited service restaurant	0.07962	1.003
Full service restaurant	0.08467	1.067
Other food service	0.07664	0.966
All commercial buildings	0.07936	1.000

Source: CBECS 2003
* This group is assumed to include convenience stores without gas stations, specialty stores (such as meat markets), and beer, wine, and liquor stores.
**This group is assumed to include mainly large multi-line retailers and supercenters that sell both grocery and non-grocery items.

The derived ratio of commercial electricity prices by building type to the overall average commercial building price was then combined with state-by-state commercial rates to derive a series of prices for each state and for each building type. Future prices were forecasted as described in section 8.2.3.2. To obtain a weighted-average national price, DOE weighted the prices paid by each business in each state by the 2012 population in each state.[3]

For evaluation purposes, the resulting electricity prices and the calculated market weighting factors can be depicted as a cumulative probability distribution. The effective prices range from approximately 6.22 cents per kilowatt-hour to approximately 31.70 cents per kilowatt-hour. Figure 8.2.1 illustrates the results for the convenience and small food retail market sector.

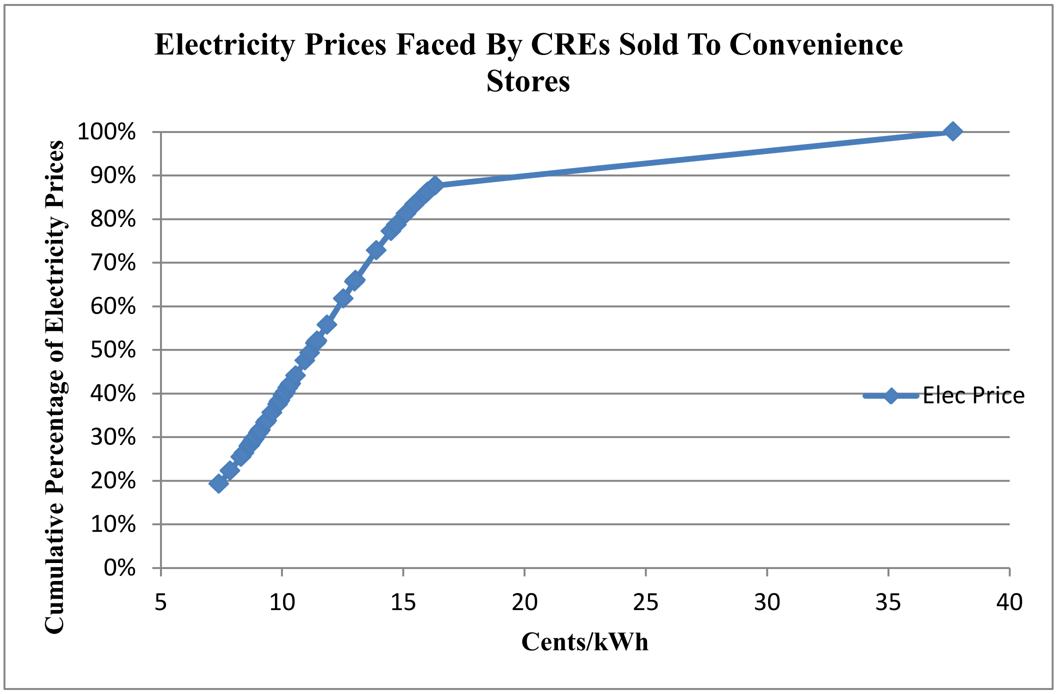


Figure 8.2.1 Cumulative Probability Distribution Showing the Electricity Prices Paid by Convenience/Small Market Sector in 2012 (2012$)

8.2.3.2 Electricity Price Trend

The electricity price trend provides the relative change in electricity prices for future years out to 2046. Estimating future electricity prices is difficult, especially considering that there are efforts in many states throughout the country to restructure the electricity supply industry.

DOE applied a projected trend in national average electricity prices to each customer's energy prices based on the *AEO2013* price scenarios. The discussion in this chapter refers to the 2012 reference price scenario. In the LCC analysis, the following four scenarios can be analyzed:

1. Constant (real) energy prices at 2012 values (*i.e.*, a constant index of 1.0 in Figure 8.2.2)
2. *AEO2013*, High Economic Growth ("AEO2013 High Growth" in Figure 8.2.2)
3. *AEO2013*, Reference Case ("AEO2013 Reference" in Figure 8.2.2)
4. *AEO2013*, Low Economic Growth ("AEO2013 Low Growth" in Figure 8.2.2)

Figure 8.2.2 shows the trends for the three *AEO2013* price projections where prices are assumed to change. DOE extrapolated the values in later years (*i.e.*, after 2040—the last year of the *AEO2013* forecast). To arrive at values for these later years, DOE used the price trend from 2031 to 2040 of each forecast scenario to establish prices for the years 2041 to 2046.

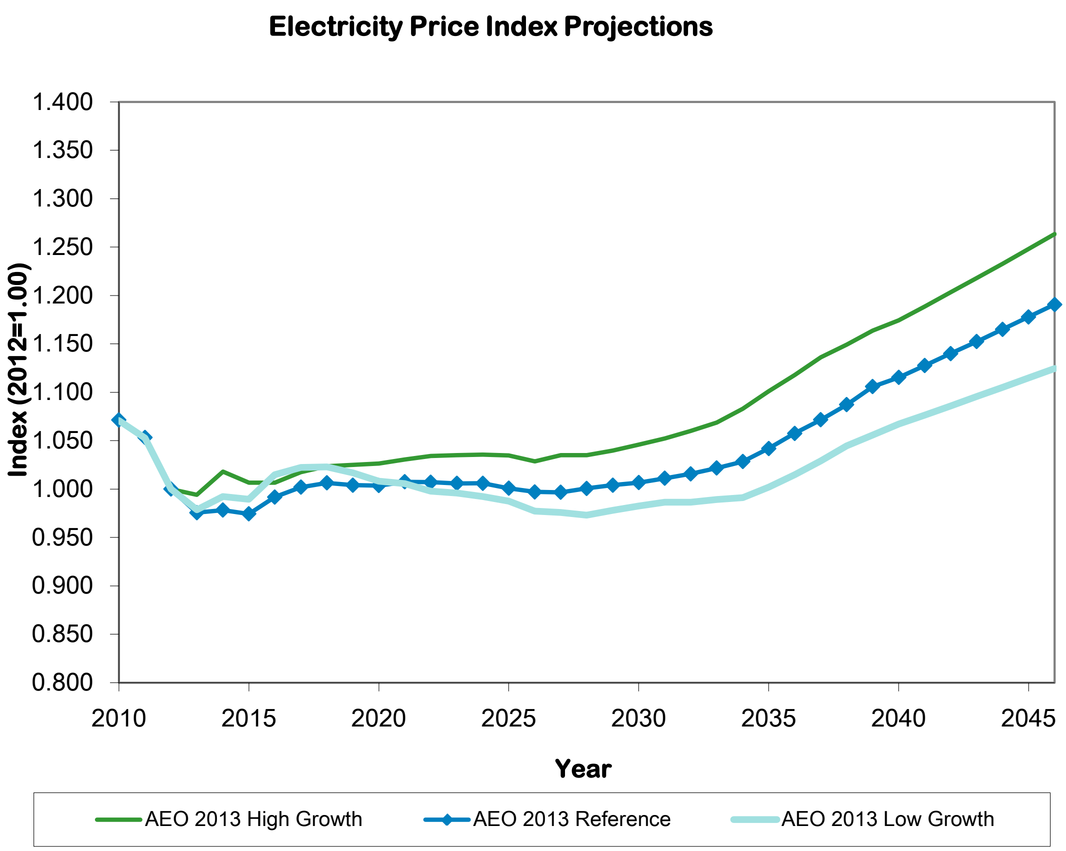


Figure 8.2.2 Electricity Price Trends for Commercial Rates to 2046

The default electricity price trend scenario used in the LCC analysis is the trend from the *AEO2013* Reference Case, shown in Figure 8.2.2. Spreadsheets used in calculating the LCC have the capability to analyze the other electricity price trend scenarios, namely, the *AEO2013* High Growth and the *AEO2013* Low Growth price trends and constant energy prices.

8.2.3.3 Repair Cost

The repair cost is the cost to the customer for replacing or repairing failed components in commercial refrigeration equipment. For the January 2009 final rule analysis, DOE obtained estimated rates of component failures as shown in Table 8.2.12. DOE based the annualized repair cost on the following expression:

$$RC = k \times EQP_{OEM} \times MU_{REPLACE}/LIFE$$

Eq. 8.7

Where:

RC = repair cost ($),
k = fraction of the components likely to be replaced during the equipment lifetime,
EQP_{OEM} = original equipment manufacturer cost of the component ($),

$MU_{REPLACE}$ = markup applied to original equipment manufacturer cost of the component to the cost to replace the component (includes the labor cost to replace/repair), and
$LIFE$ = lifetime of the equipment in years.

As the components used for higher efficiency commercial refrigeration equipment have a higher original equipment manufacturer (OEM) cost, Eq. 8.7 yields an increasing repair costs scenario for higher efficiency equipment.

There are other refrigeration parts that typically require repair, such as door handles, hinges, shelves, drain pans, and condensate pan heaters. However, these parts are the same for all efficiency levels, so the repair costs for these parts remain constant for all efficiency levels. Therefore, these additional repair costs were not taken into consideration for the analysis.

Table 8.2.12 Estimated Replacement Rate of Components During Equipment Service Life (Values Retained from January 2009 Final Rule Analysis)

Component	Estimated Replacement Rate (over 10 year period)
Evaporator fans	50%
Condenser fans	25%
Compressors	25%
Coils*	5%
Doors	5%

*Applied only to remote condensing equipment

8.2.3.4 Maintenance Costs

Maintenance costs are the costs to the customer of maintaining installed equipment. Maintenance costs are not the costs associated with the replacement or repair of components that have failed (as discussed in section 8.2.3.3). Rather, they are the costs associated with general maintenance.

DOE obtained annualized maintenance costs for commercial refrigeration equipment from data in *RS Means Facilities Maintenance & Repair Cost Data.*[4] *RS Means* provides estimates on the person-hours, labor rates, and materials required to maintain commercial refrigeration equipment. *RS Means* specifies preventative maintenance activities for commercial display cases expected to occur on a semi-annual basis as including the following actions: cleaning evaporator coils, drain pans, fans, and intake screens; lubricating motors; inspecting door gaskets and seals, and lubricating hinges; cleaning condenser coils; checking refrigerant pressures and compressor oil as necessary; checking starter panels and controls; and checking defrost system operation. From the *RS Means* data DOE obtained costs of $220 per year (2012$) for preventative maintenance activities for all remote condensing equipment classes and $35 per year (2012$) for self-contained equipment classes. Because data were not available to indicate how maintenance costs vary with CSL, DOE decided to use preventative maintenance costs that remain constant as equipment efficiency is increased. It should be noted that since the preventative maintenance cost is assumed to be constant over all CSLs within an equipment class, it does not affect the LCC analysis or NIA results because only costs that vary with CSLs (incremental costs) lead to changes in these results.

DOE considered lamp replacements and other lighting maintenance activities as required maintenance for commercial refrigeration equipment, and apart from preventative maintenance. Thus, DOE did not itemize them in the preventative maintenance activities described by *RS Means*. Different commercial refrigeration equipment classes have different numbers of lamps (and ballasts), and many of the technologies DOE considered in the engineering analysis involved changes to the lighting configuration (lamp, ballast, or use of LED lighting systems). Because the lighting configurations can vary by CSL, DOE estimated the relative maintenance costs for lighting for each equipment class at each CSL. 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 based on the sum of the total lighting maintenance costs (in 2012$) over the estimated life of the equipment divided by the estimated life of the equipment.

Lifetime estimates for particular lighting components were as follows:

- Fluorescent lamps would be replaced every 24 months in a preventative fashion.
- Fluorescent lamp ballasts would be replaced once over the estimated 10-year life of the equipment based on a typical ballast life of 80,000 hours.
- LED lamps would be replaced once every 5.7 years based on a typical fixture life of 50,000 hours.[5]

The approach taken was to estimate the costs of field replacement using labor cost hours from *RS Means Electrical Cost Data*[6] for typical lamp or ballast replacement as baseline values. The costs for replacement of lamps and ballasts can be split into cost of material and cost of labor. The cost of labor was determined from the RS Means database as the cost to replace one fluorescent bulb and the cost to replace one fluorescent lamp ballast. The cost of equipment was determined by using the OEM costs of the lamps and ballasts and applying material cost markups to reflect retail pricing as explained below.

DOE estimated the material cost markup to be 250 percent by comparing the OEM costs of fluorescent lamps and ballasts with typical retail prices. However, typically, when large food retailers replace lamps or ballasts in their display cases, they tend to replace the lamps and ballasts in all display cases at the same time. Large food retailers house a large number of remote condensing display cases, and therefore tend to purchase lamps and ballasts in bulk. DOE estimated that through such bulk purchases large food retailers are able to negotiate a large-volume discount. Therefore, for remote condensing equipment, the material cost markup was assumed to be a 150-percent multiplier on OEM costs for lamps and ballasts. Small businesses, such as restaurants, that typically house only self-contained equipment do not get such a volume discount because they do not purchase a large number of lamps and ballasts. Therefore, for self-contained equipment, the material cost markup was assumed to be a 250-percent multiplier on OEM costs for lamps and ballasts to reflect retail pricing. DOE is aware that many large food retail stores also house self-contained equipment, and some small businesses may use remote condensing equipment. However, DOE does not have the data to reliably determine the fraction of self-contained equipment in large food retail stores and the remote condensing equipment in small business establishments. DOE believes the assumptions detailed in this section reflect a reasonable compromise in the calculation of the lighting maintenance costs.

Based on the cost values from RS Means database, the typical markup value on labor costs (labor cost markup) was calculated to be approximately 157 percent. However, this labor cost markup was applied to the RS Means labor cost values for self-contained equipment only. No labor cost markup was applied to the RS Means labor cost values for remote condensing equipment. Once again, the assumption was that the remote condensing equipment that is housed mainly in large food retail stores has the advantage of volume discount, whereas self-contained equipment, which is typically housed in small business establishments, does not have the advantage of volume discount. In effect, no markup for remote condensing equipment amounts to the assumption that large food retailers use in-house labor for replacement of lamps and ballasts. DOE believes these assumptions provide reasonably accurate estimates for lighting maintenance costs.

The lamp and ballast replacement costs obtained from the RS Means database are applicable for replacement of lamps and ballasts in overhead lamp fixtures. The labor effort and time involved in replacing lamps and ballasts in display cases is much lower compared those associated with overhead lamp fixtures. DOE assumed that the labor costs for replacing lamps and ballasts in display cases would be about half of the costs for overhead lamp fixtures.

Fluorescent lamp and ballast technology is mature. Available information suggests that there would be no change in inflation-adjusted costs for these components. However, because of rapid technological improvement, costs for LED lamps are declining. As discussed in TSD chapter 5, DOE estimated the annual reduction in the prices of LED lamps from 2013 through 2030. DOE used these price reductions to estimate the cost of LED lamps in 2022, 6 years into the compliance date of this rule when LED lamps would be first replaced for equipment installed in the year of compliance (2017).

DOE determined that the effort required to replace a fluorescent lamp ballast is similar to the effort required to replace the power supply (driver) of an LED lamp. However, replacement of LED lamps involves additional effort to replace the LED lighting fixture. DOE estimated that the total labor cost to replace an LED lamp (lighting fixture and power supply) would be approximately 25 percent higher than the cost to replace a fluorescent lamp ballast. The assumption of material cost markup (of 150-percent for remote condensing equipment and 250-percent for self-contained equipment) was retained for LED lamps replacement cost estimation.

The total costs for lamp, ballast, or LED fixture replacement were annualized by dividing the total estimated replacement costs over the lifetime of commercial refrigeration equipment as shown in Eq. 8.8.

$$Annualized\ Lighting\ Maintenance\ Cost = \frac{1}{Life}\sum_{Life}\Big\{OEM\_Cost_{Lamp/Ballast} \times Markup_{Retail} + \left(N_{Bulb} \times Labor_{Bulb} + N_{Ballast} \times Labor_{Ballast} + N_{LED\_Lamps} \times Labor_{LED\_Lamps}\right) \times Markup_{Labor}\Big\}$$

Eq. 8.8

Where:

Annualized Lighting Maintenance Cost = annualized lighting maintenance cost ($) for an efficiency level,
Life = commercial refrigeration equipment lifetime (years),
$OEM\_Cost_{Lamp/Ballast}$ = OEM costs for all the fluorescent bulbs, LED lamps, and fluorescent lamp ballasts in each unit of equipment; obtained from engineering analysis (TSD chapter 5) ($),
$Markup_{Retail}$ = 250 percent for self-contained equipment, and 150 percent for remote condensing equipment,
N_{Bulb} = number of fluorescent bulbs in the particular efficiency level of the equipment class analyzed,
$Labor_{Bulb}$ = labor cost to replace one fluorescent bulb ($),
$N_{Ballast}$ = number of fluorescent lamp ballasts in the particular efficiency level of equipment class analyzed,
$Labor_{Ballast}$ = labor cost to replace one fluorescent ballast ($),
N_{LED_Lamps} = number of LED lamps in the particular efficiency level of equipment class analyzed,
$Labor_{LED\_Lamps}$ = labor cost to replace one LED lamp, including the power supply ($). This value is 1.25 times $Labor_{Ballast}$, and
$Markup_{Labor}$ = 157 percent for self-contained equipment, and 100 percent for remote condensing equipment.

Table 8.2.13 shows the annualized lighting maintenance costs for each efficiency level for the representative units defined in the engineering analysis. Total annualized maintenance costs are the sum of the preventative maintenance and the lighting maintenance costs.

Table 8.2.13 Annualized Lighting Maintenance Costs by Equipment Class for Each CSL for the Representative Units Analyzed in the Engineering Analysis

Equipment Class	Annualized Lighting Maintenance Costs by Efficiency Level *2012$/yr*							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	95.86	95.86	95.86	118.53	118.53	118.53	NA	NA
VOP.RC.L	41.08	41.08	35.85	35.85	35.85	NA	NA	NA
VOP.SC.M	55.02	55.02	55.02	55.02	63.96	63.96	63.96	NA
VCT.RC.M	32.35	32.35	32.35	32.35	32.35	32.35	32.35	NA
VCT.RC.L	32.35	32.35	32.35	32.35	32.35	32.35	NA	NA
VCT.SC.M	23.85	23.85	23.85	23.85	23.85	23.85	23.85	23.85
VCT.SC.L	42.89	23.85	23.85	23.85	23.85	23.85	23.85	23.85
VCT.SC.I	23.85	23.85	23.85	23.85	23.85	23.85	23.85	NA
VCS.SC.M	-	-	-	-	-	-	-	-
VCS.SC.L	-	-	-	-	-	-	-	-
VCS.SC.I	-	-	-	-	-	-	-	NA
SVO.RC.M	68.47	68.47	68.47	92.36	92.36	92.36	NA	NA
SVO.SC.M	38.50	38.50	38.50	38.50	49.74	49.74	49.74	NA
SOC.RC.M	68.47	68.47	68.47	71.69	71.69	71.69	71.69	NA
HZO.RC.M	-	-	NA	NA	NA	NA	NA	NA
HZO.RC.L	-	-	NA	NA	NA	NA	NA	NA
HZO.SC.M	-	-	-	-	-	NA	NA	NA
HZO.SC.L	-	-	NA	NA	NA	NA	NA	NA
HCT.SC.M	-	-	-	-	-	-	-	-
HCT.SC.L	-	-	-	-	-	-	-	-
HCT.SC.I	-	-	-	-	-	NA	NA	NA
HCS.SC.M	-	-	-	-	-	-	-	NA
HCS.SC.L	-	-	-	-	-	-	-	NA
PD.SC.M	12.73	14.45	14.45	14.45	14.45	14.45	14.45	14.45
SOC.SC.M	93.15	109.88	109.88	109.88	115.70	115.70	115.70	115.70

"-" is used for equipment classes that do not feature lighting. NA implies there are no associated efficiency levels.

8.2.3.5 Lifetime

DOE defines lifetime as the age at which a commercial refrigeration equipment unit is retired from service. DOE based its estimates of equipment lifetime on discussions with industry experts and concluded that a typical lifetime of 10 years is appropriate for most commercial refrigeration equipment in large grocery/multi-line stores and restaurants. TSD chapter 3, Market and Technology Assessment, discusses equipment life and tabulates estimates from various sources used in assessing equipment life. Remote condensing commercial refrigeration equipment units typically are replaced when stores are renovated, which is before the commercial refrigeration equipment units would have physically worn out. Typically, the gap between store renovations is around 8 to 9 years for major store chains.[7] DOE assumed that an average grocery store or supermarket renovates every 10 years. Because some equipment thus has remaining useful life, there is a market for commercial refrigeration equipment that has been removed from service. DOE understands, however, that the salvage value to the original purchaser is very low, and thus has not taken this into account in the LCC. Operators of small food retail stores, on the other hand, tend to use display cases for a longer duration. DOE used 15 years as the average equipment lifetime for display cases used in such retail stores.

DOE assumed the average lifetime of all self-contained equipment to be 10 years based on discussions with various retailers, manufacturers, and industry experts. During the preliminary analysis public meeting, the stakeholders generally agreed that 10 years is a reasonable estimate for the lifetime of self-contained equipment.

To account for uncertainty and variability, DOE determined the probability that a unit of commercial refrigeration equipment of age *a* will break or will be replaced using a Weibull survival distribution function *W(8,10.62)* for display cases in large grocery stores and supermarkets, and all self-contained equipment. This Weibull survival function (Figure 8.2.3) yielded an average lifetime of 10 years. The minimum lifetime was truncated at 5 years, and the maximum lifetime was truncated at 15 years to remove the unrealistic probabilities associated with the lifetimes outside this range, which were mostly an artifact of the assumption of the Weibull function. For display cases used in small grocery stores, the equipment lifetimes were represented by the Weibull function *W(8,16)*, which yielded an average lifetime of 15 years. The Weibull function was truncated above and below the range of 10 to 20 years (Figure 8.2.4) to remove the unrealistic probabilities associated with the lifetimes outside this range, which were mostly an artifact of the assumption of the Weibull function. The probabilities of failure in a given future year for both equipment lifetime categories are shown on Table 8.2.14.

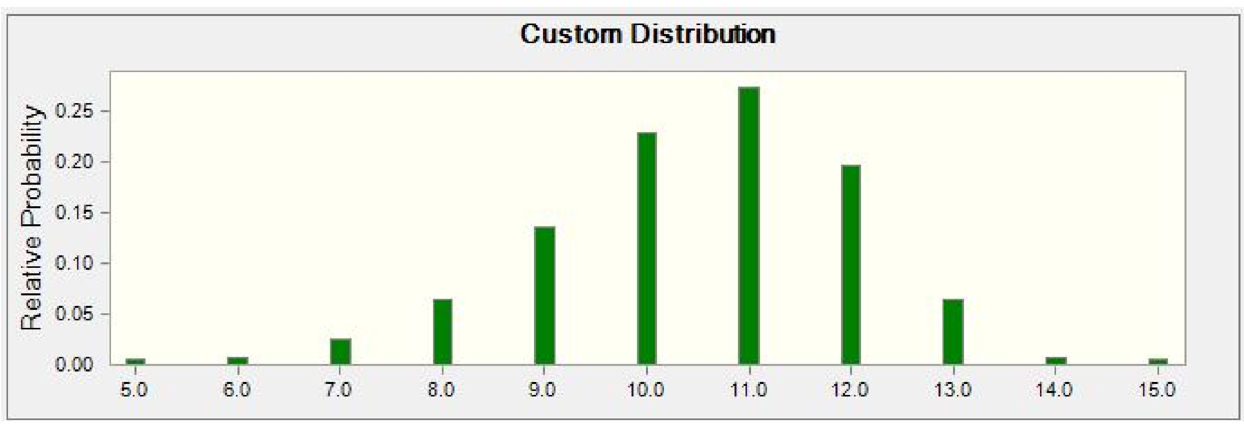


Figure 8.2.3 Survival Function for Display Cases in Large Grocery Stores and Supermarkets and for All Self-Contained Equipment

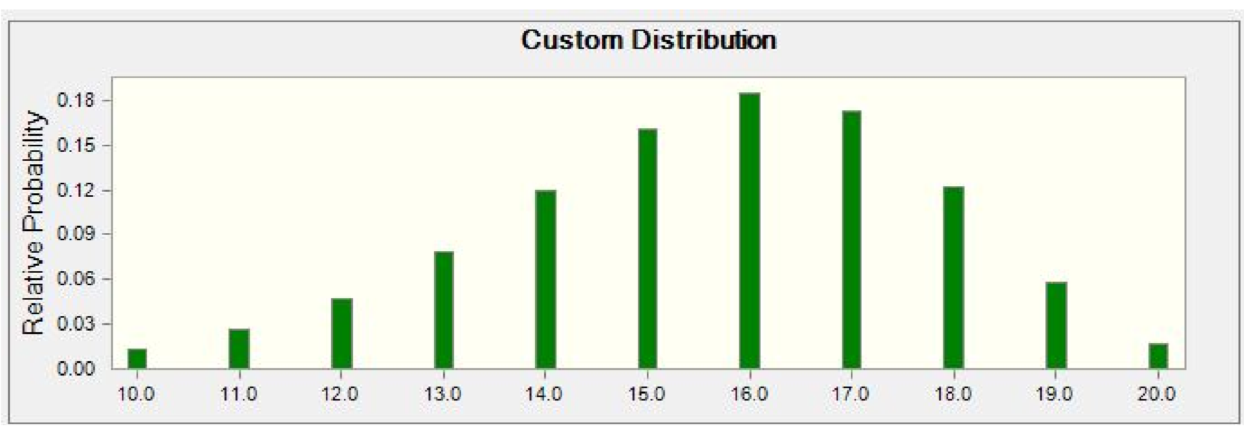


Figure 8.2.4 Survival Function for Display Cases in Small Grocery Stores

Table 8.2.14 Probability of Equipment Failure by Year

Year	10-Year Equipment	15-Year Equipment
5	0.2%	
6	0.8%	
7	2.5%	
8	6.4%	
9	13.5%	
10	22.7%	1.3%
11	27.3%	2.6%
12	19.6%	4.7%
13	6.4%	7.9%
14	0.6%	11.9%
15	0.0%	16.1%
16		18.5%
17		17.3%
18		12.2%
19		5.8%
20		1.7%

8.2.3.6 Discount Rate

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).[8] 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:

$$k_e = R_f + (\beta \text{ x } ERP)$$

Eq. 8.9

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 1973 to 2012,[9] with a resulting rate of 6.41 percent. DOE used a 3.99 percent estimate for the *ERP* based on the difference between the risk-free rate and a 40-year average return on the S&P 500 index derived from data from the Damodaran Online[10] 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. 8.10

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.[11] The weighted-average cost of capital (WACC) of a company is the weighted-average cost of debt and equity financing:

$$k = k_e \, x \, w_e + k_d \, x \, w_d$$

Eq. 8.11

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 inflation (3.68 percent) as the 40-year average gross domestic product deflator derived from U.S. Bureau of Labor Statistics data covering the 1973–2012 period.[12]

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.

Table 8.2.15 outlines the building type and ownership categories as well as the number of companies used for determining discount rates. For five of the seven building categories there is a mixture of large companies with stock traded on major U.S. stock exchanges and smaller companies that are not publicly traded—*e.g.*, single-store or small, local chains of convenience stores or restaurants. The cost of capital for small, independent grocers, convenience store franchisees, gasoline station owner-operators, and others with more limited access to capital is more difficult to determine than for publicly traded companies. Individual credit-worthiness varies considerably, and some franchisees have access to the financial resources of the franchising corporation. To model this cost of capital difference, DOE uses a small business premium of 1.9 percent (real) based on data compiled from the Small Business Administration website.[13]

Table 8.2.15 Derivation of Real Discount Rates by Building Type

Building Type Description	Major Chain		Local or Non-Chain		Governmental			No. Obs.*
	WACC	Percent of Stock	Small Firm Premium	Percent of Stock	Muni Bond Rate	Percent of Stock	Discount Rate	
Large Grocery	4.16%	100%	0.0%	0%	0%	0%	4.16%	18
Small Grocery & Convenience	4.20%	50%	1.9%	50%	0%	0%	5.19%	5
Gas Station With Convenience Store	4.20%	50%	1.9%	50%	0%	0%	5.19%	NA
Multi-Line Retail	4.33%	100%	0.0%	0%	0%	0%	4.33%	6
Restaurant - Limited Service	5.29%	50%	1.9%	50%	0%	0%	6.29%	21
Restaurant - Full Service	5.61%	50%	1.9%	50%	0%	0%	6.62%	24
Restaurant - Other Food Service	5.61%	25%	1.9%	25%	2.34%	50%	4.48%	NA

Source: Pacific Northwest National Laboratory (PNNL) WACC calculations applied to firms sampled from the Damodaran Online web site. Assumptions for weighting factors for convenience and food service reflect lack of reliable data sources.
*Number of Damodaran observations available.

For two building types, Gas Station with Convenience Store and Restaurant – Other Food Service, no representative data was identifiable in the Damodaran database. Gas Station with Convenience Store was set equal to the discount rate for Small Grocery and Convenience. Other

Food Service was based on the WACC derived for Full Service Restaurants. The main difference between the resulting discount rate is that a significant portion of this building category consists of cafeterias, a large percentage of which are located in schools, universities, and governmental buildings. No data exist on the exact percentage, so it was weighted as 50 percent schools and 50 percent privately owned. The discount rate for schools, universities, and governmental buildings was set equal to a 40-year geometric average of municipal bond rates, mixed quality, obtained from the Federal Reserve Bank of St. Louis.[14]

DOE's research identified multiple data sources indicating the percentages of building stock represented by major chains and by local or non-chain establishments. All of the data sources exhibited ambiguities and in many cases contradicted other data sources. For the NOPR, the percentages were set to approximate, round values to reflect the uncertainty of the data, as shown in Table 8.2.15. Both Large Grocery and Multi-Line Retail were assumed to be dominated by major chains, and the percentage divisions were set accordingly.

8.2.3.7 Compliance Date of Standard

The compliance date is the future date after which all manufacturers selling equipment in the United States should comply by the standards. Under 42 U.S.C. 6313(a)(6)(c), the compliance date of any new energy conservation standard for commercial refrigeration equipment will be 3 years after the final rule is published. DOE calculated the LCC for all customers as if they each would purchase a new commercial refrigeration equipment unit in the year starting on the compliance date. Consistent with its published regulatory agenda, DOE assumed that the final rule will be issued in 2014 and therefore the compliance date for the new standards will be in 2017. For the LCC analysis, the year of equipment purchase was assumed to be 2017. All dollar values are expressed in 2012$.

8.3 PAYBACK PERIOD INPUTS

8.3.1 Definition

Payback period is the amount of time it takes the customer to recover the 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 to the decrease in annual operating expenditures. This type of calculation is known as a "simple" payback period because it does not take into account changes in operating 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:

$$PBP = \Delta IC / \Delta OC$$

Eq. 8.12

Where:

PBP = payback period in years,

ΔIC = difference in the total installed cost between the CSL and the baseline level equipment, and
ΔOC = difference in the first year annual operating costs between the CSL and the baseline level equipment.

PBPs are expressed in years. PBPs greater than the life of the product mean that the increased total installed cost of the CSL is not likely to be recovered in reduced operating costs over the life of the equipment.

8.3.2 Inputs

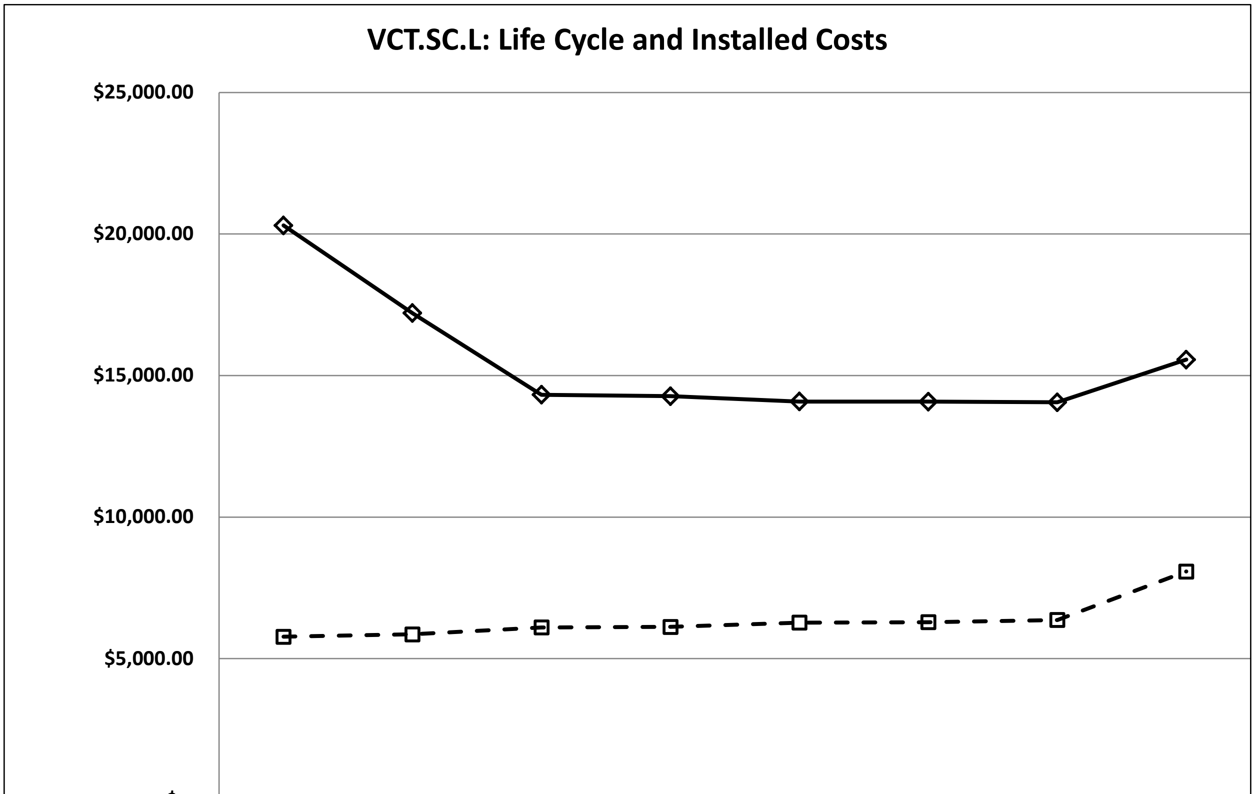
The data inputs to PBP are the total installed cost of the equipment to the customer for each CSL and the annual (first year) operating costs for each CSL. The inputs to the total installed cost are the equipment price and the installation cost. The inputs to the operating costs are the annual energy cost, the annual repair cost, and the annual maintenance cost. The PBP calculation uses the same inputs as the LCC analysis described in section 8.2, except that electricity price trends and discount rates are not required because the PBP is a "simple" (undiscounted) payback and the required electricity price is only for the year in which a new efficiency standard is to take effect—in this case, the year 2017. The electricity price used in the PBP calculation of electricity cost was the price projected for 2017, expressed in 2012$. Discount rates are not used in the PBP calculation.

8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

This section presents the results of the LCC and PBP analysis, including the mean and median values of LCC savings and PBP. Appendix 8B presents additional details along with distribution of impacts on customers.

8.4.1 Life-Cycle Cost Results

Figure 8.4.1 shows the change in LCC over the eight efficiency levels for an example equipment class (VCT.SC.L). The LCC values on this chart are mean values obtained from the LCC analysis. This curve is presented here as an example to illustrate the typical relationship between installation cost and LCC over all the efficiency levels for an equipment class. The installed costs increase steadily from the baseline to the highest possible efficiency level (Level 8) and the LCCs decrease from Level 1 to Level 7. The increase in installed cost from Level 7 to Level 8 is not offset by the decrease in operating cost because of the large increase in installed cost with relatively small gains in energy savings. Therefore, for this equipment class there is an increase in LCC at Level 8 when compared to Level 7.



	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
Life Cycle Cost	$20,302.86	$17,205.24	$14,322.65	$14,270.45	$14,081.92	$14,076.18	$14,055.79	$15,562.45
Installed Cost	$5,773.19	$5,860.64	$6,100.60	$6,120.37	$6,270.65	$6,286.11	$6,363.86	$8,076.92

Figure 8.4.1 LCC and Installed Cost Variation over CSLs for the VCT.SC.L Equipment Class

Since the LCC analysis was carried out in the form of Monte Carlo simulations, the LCC savings outputs obtained from the LCC analysis are in the form of distributions. LCC savings distributions are illustrated here with the example of the VCT.SC.L equipment class as shown in Figure 8.4.2. Similar plots of LCC savings distribution are presented in appendix 8B for all equipment classes analyzed. Table 8.4.1 presents the numerical values associated with the plot in Figure 8.4.2. Figure 8.4.2 illustrates the mean and median values on the plot with the help of red and blue markers, respectively. The elongated large rectangular box is used to represent the 25th and 75th percentile values. The lower edge of the elongated rectangle represents 25th percentile, which means that 25 percent of the customers would experience LCC savings of $2,498 or less if the standard were to be set at Level 2, $2,658 or less in LCC savings if the standards were set at Level 3, and so on. The median value of LCC savings is equal to the 50th percentile. The upper edge of the elongated rectangle represents the 75th percentile. The two ends of the vertical black line for each efficiency level represent the 5th percentile (lower end) and 95th percentile (upper end).

Mean and median LCC savings for all equipment classes analyzed are summarized in Table 8.4.2 and Table 8.4.3, respectively.

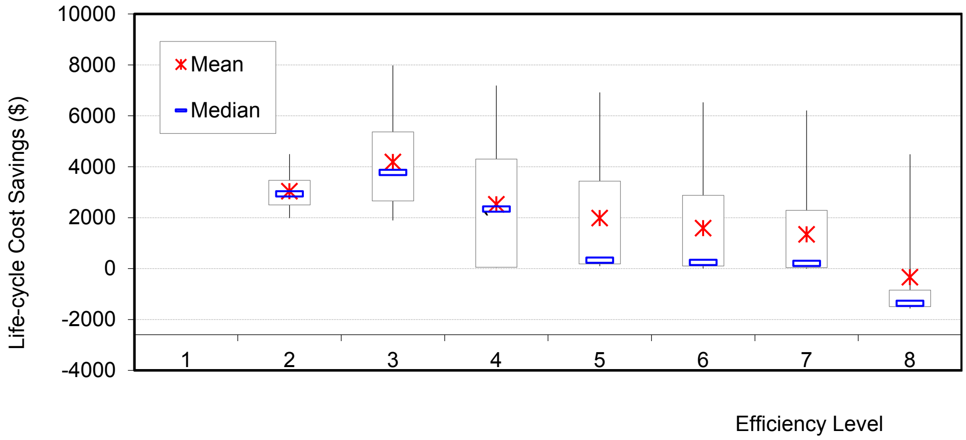


Figure 8.4.2 LCC Savings Distribution for All the CSLs for Equipment Class VCT.SC.L

Table 8.4.1 LCC Savings Distribution Results for Equipment Class VCT.SC.L

	Efficiency Level	**2**	**3**	**4**	**5**	**6**	**7**	**8**
LCC Savings* ***2012$***	**Mean**	3,037	4,186	2,523	1,984	1,587	1,343	(343)
	Median (50th Percentile)	2,931	3,773	2,333	323	239	196	(1,370)
	5th Percentile	1,987	1,889	32	96	0	(6)	(1,572)
	25th Percentile	2,498	2,658	53	181	101	36	(1,495)
	75th Percentile	3,464	5,369	4,302	3,433	2,877	2,283	(847)
	95th Percentile	4,494	7,978	7,191	6,921	6,529	6,210	4,491

* Values in parentheses are negative numbers.

Table 8.4.2 Mean LCC Savings for All Equipment Classes and CSLs

Equipment Class	Mean LCC Savings*** *2012$*						
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	$235.92	$743.00	$1,788.85	$1,493.72	($1,668.79)	NA	NA
VOP.RC.L	$537.27	$1,516.59	$1,129.51	($3,692.90)	NA	NA	NA
VOP.SC.M	$115.53	$170.78	$227.17	$814.91	$691.27	($376.52)	NA
VCT.RC.M	$175.23	$1,864.44	$1,758.73	$1,363.59	$1,108.13	($2,508.61)	NA
VCT.RC.L	$1,658.64	$1,357.25	$1,004.72	$797.91	($3,624.20)	NA	NA
VCT.SC.M	$566.18	$1,363.60	$1,122.14	$894.21	$748.09	$641.05	($595.52)
VCT.SC.L	$3,037.41	$4,186.06	$2,522.67	$1,984.45	$1,587.41	$1,342.84	($343.16)
VCT.SC.I	$1,151.77	$572.05	$608.48	$486.28	$431.88	($1,591.87)	NA
VCS.SC.M	$508.27	$278.84	$195.52	$162.88	$144.16	$131.80	($1,042.03)
VCS.SC.L	$924.24	$524.52	$382.36	$329.33	$267.81	$220.83	($1,274.03)
VCS.SC.I	$6.93	$236.77	$171.90	$176.83	$152.69	($1,818.87)	NA
SVO.RC.M	$73.77	$551.98	$1,216.77	$1,008.46	($1,015.16)	NA	NA
SVO.SC.M	$21.89	$324.33	$334.89	$587.90	$491.99	($201.61)	NA
SOC.RC.M	$118.36	$226.26	$997.89	$765.75	$494.51	($982.21)	NA
HZO.RC.M	($1,271.24)	NA	NA	NA	NA	NA	NA
HZO.RC.L	($2,134.96)	NA	NA	NA	NA	NA	NA
HZO.SC.M	$8.85	$48.60	$28.78	($821.57)	NA	NA	NA
HZO.SC.L	($473.71)	NA	NA	NA	NA	NA	NA
HCT.SC.M	$99.20	$106.59	$117.59	$359.48	$307.26	$253.60	($293.54)
HCT.SC.L	$204.67	$217.19	$790.53	$571.07	$446.02	$368.92	($354.75)
HCT.SC.I	$21.83	$34.69	$42.48	($811.31)	NA	NA	NA
HCS.SC.M	$23.07	$19.18	$16.66	$8.68	($10.26)	($422.79)	NA
HCS.SC.L	$68.03	$71.83	$74.69	$80.97	$80.72	($400.63)	NA
PD.SC.M	$1,009.53	$933.59	$615.94	$456.97	$368.81	$310.43	($637.94)
SOC.SC.M	$794.63	$646.15	$466.47	$1,241.60	$1,015.62	$739.75	($735.33)

* NA implies there are no associated CSLs.
**Values in parentheses are negative values.

Table 8.4.3 Median LCC Savings for All Equipment Classes and CSLs

Equipment Class	Median LCC Savings*** *2012$*						
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	$218.97	$692.78	$1,597.21	$1,386.60	($1,769.27)	NA	NA
VOP.RC.L	$499.00	$1,414.37	$1,189.56	($3,852.38)	NA	NA	NA
VOP.SC.M	$109.17	$159.78	$203.28	$737.39	$655.36	($393.19)	NA
VCT.RC.M	$161.37	$1,698.77	$1,720.74	$1,300.46	$535.18	($3,164.25)	NA
VCT.RC.L	$1,548.46	$1,007.99	$590.56	$330.01	($4,069.46)	NA	NA
VCT.SC.M	$540.88	$1,263.78	$1,144.46	$835.95	$267.37	$142.91	($1,093.09)
VCT.SC.L	$2,930.96	$3,772.61	$2,332.55	$323.16	$238.78	$195.53	($1,370.50)
VCT.SC.I	$1,106.11	$48.55	$292.20	$244.77	$210.18	($1,814.20)	NA
VCS.SC.M	$476.34	$63.09	$49.96	$47.04	$46.03	$44.77	($1,118.86)
VCS.SC.L	$870.59	$159.76	$141.53	$129.48	$91.41	$62.97	($1,411.62)
VCS.SC.I	$6.50	$220.74	$199.83	$128.26	$87.82	($1,865.05)	NA
SVO.RC.M	$67.77	$502.00	$1,052.23	$882.01	($1,151.94)	NA	NA
SVO.SC.M	$20.87	$305.70	$342.61	$527.63	$442.48	($262.18)	NA
SOC.RC.M	$107.95	$211.62	$895.27	$751.76	$490.36	($1,061.05)	NA
HZO.RC.M	($1,273.12)	NA	NA	NA	NA	NA	NA
HZO.RC.L	($2,143.56)	NA	NA	NA	NA	NA	NA
HZO.SC.M	$8.38	$45.07	$25.02	($830.11)	NA	NA	NA
HZO.SC.L	($475.85)	NA	NA	NA	NA	NA	NA
HCT.SC.M	$93.69	$92.35	$96.94	$332.55	$304.32	$260.44	($294.96)
HCT.SC.L	$190.27	$184.31	$737.43	$613.99	$483.70	$31.61	($630.30)
HCT.SC.I	$20.55	$32.43	$36.45	($824.21)	NA	NA	NA
HCS.SC.M	$21.79	$15.60	$10.06	$2.40	($16.02)	($426.21)	NA
HCS.SC.L	$64.38	$60.95	$60.13	$66.76	$63.51	($420.71)	NA
PD.SC.M	$968.08	$720.68	$431.23	$9.94	$38.80	$9.34	($903.62)
SOC.SC.M	$730.27	$431.69	$267.79	$1,076.79	$916.50	$665.93	($829.93)

* NA implies there are no associated CSLs.
**Values in parentheses are negative values.

8.4.2 Payback Period Results

Figure 8.4.3 presents the distribution of the PBP results for CSLs 2 to 8 of an example equipment class (VCT.SC.L). The numerical values associated with this plot are presented in Table 8.4.4. The red marker represents the mean and the blue marker represents the median PBP for each CSL. The lower edge of the elongated rectangular box represents the 25th percentile, which means that 25 percent of the customers would experience a PBP of 0.25 years or less if the energy conservation standard were to be set at Level 2, 0.47 years or less if the energy conservation standard were to be set at Level 3, and so on. The upper edge of the rectangular box represents the 75th percentile. The two ends of the vertical line represent the 5th percentile (lower end) and 95th percentile (upper end). Table 8.4.5 and Table 8.4.6 summarize the mean and median PBPs, respectively, for all CSLs of all the analyzed equipment classes. Results similar to Figure 8.4.3 are presented in appendix 8B for all equipment classes.

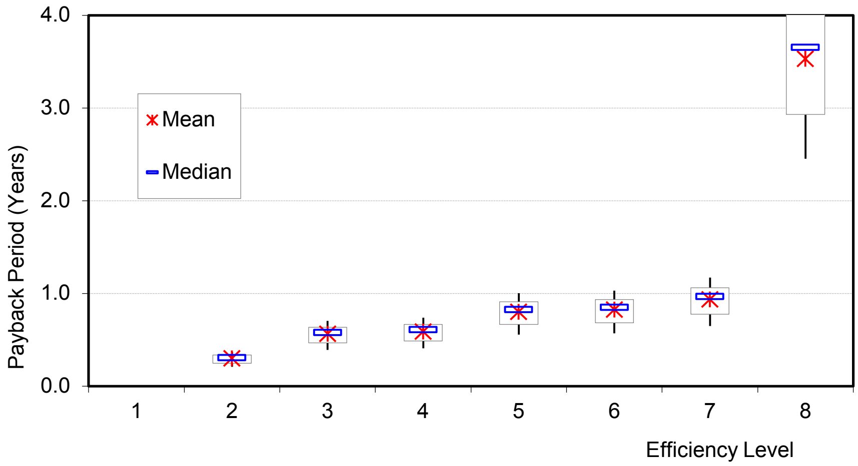


Figure 8.4.3 Mean Payback Period for All CSLs for the Equipment Class VCT.SC.L

Table 8.4.4 Payback Period Distribution Results for VCT.SC.L

	CSL	2	3	4	5	6	7	8
Payback period *years*	**Mean**	0.29	0.56	0.59	0.80	0.82	0.93	3.53
	Median (50th Percentile)	0.31	0.58	0.61	0.83	0.85	0.96	3.65
	5th Percentile	0.21	0.39	0.41	0.56	0.57	0.65	2.45
	25th Percentile	0.25	0.47	0.49	0.66	0.68	0.77	2.93
	75th Percentile	0.33	0.64	0.67	0.91	0.93	1.06	4.01
	95th Percentile	0.37	0.70	0.74	1.00	1.03	1.17	4.43

Table 8.4.5 Mean Payback Period for All Equipment Classes and CSLs

Equipment Class	Mean Payback Period* *years*						
	Level 2	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**
VOP.RC.M	1.67	1.72	3.66	3.79	11.42	NA	NA
VOP.RC.L	1.08	1.97	2.16	17.76	NA	NA	NA
VOP.SC.M	1.51	1.63	2.20	4.17	4.44	11.50	NA
VCT.RC.M	1.20	2.34	2.36	2.54	2.61	12.67	NA
VCT.RC.L	0.95	1.26	1.46	1.59	15.25	NA	NA
VCT.SC.M	0.83	1.67	2.13	2.22	2.41	2.45	7.84
VCT.SC.L	0.29	0.56	0.59	0.80	0.82	0.93	3.53
VCT.SC.I	0.75	0.86	1.63	1.75	1.98	13.26	NA
VCS.SC.M	0.72	0.75	0.80	0.96	1.21	1.71	13.73
VCS.SC.L	0.48	0.54	0.57	0.88	0.97	1.12	10.26
VCS.SC.I	0.62	0.78	1.15	2.02	2.35	26.46	NA
SVO.RC.M	1.26	2.55	4.20	4.36	11.23	NA	NA
SVO.SC.M	1.21	1.93	2.02	4.34	4.66	10.16	NA
SOC.RC.M	1.21	1.39	3.21	3.44	4.27	11.51	NA
HZO.RC.M	157.02	NA	NA	NA	NA	NA	NA
HZO.RC.L	81.59	NA	NA	NA	NA	NA	NA
HZO.SC.M	1.85	2.37	6.25	54.42	NA	NA	NA
HZO.SC.L	71.79	NA	NA	NA	NA	NA	NA
HCT.SC.M	0.47	0.68	0.86	2.19	2.37	3.02	12.01
HCT.SC.L	0.34	0.52	0.99	1.03	1.14	1.45	7.06
HCT.SC.I	0.87	2.35	4.21	27.56	NA	NA	NA
HCS.SC.M	0.48	1.60	2.47	4.18	7.24	33.15	NA
HCS.SC.L	0.25	0.57	0.84	1.33	2.50	14.58	NA
PD.SC.M	0.52	1.08	1.12	1.19	1.95	2.21	7.43
SOC.SC.M	1.01	1.09	1.21	2.28	2.42	2.91	7.21

* NA implies there are no associated CSLs.

Table 8.4.6 Median Payback Period for All Equipment Classes and CSLs

Equipment Class	Median Payback Period* *years*						
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	1.73	1.77	3.77	3.91	11.76	NA	NA
VOP.RC.L	1.11	2.03	2.22	18.30	NA	NA	NA
VOP.SC.M	1.50	1.61	2.17	4.12	4.39	11.37	NA
VCT.RC.M	1.23	2.42	2.43	2.62	2.70	13.09	NA
VCT.RC.L	0.98	1.30	1.51	1.64	15.75	NA	NA
VCT.SC.M	0.86	1.73	2.21	2.30	2.49	2.54	8.13
VCT.SC.L	0.31	0.58	0.61	0.83	0.85	0.96	3.65
VCT.SC.I	0.75	0.86	1.63	1.74	1.97	13.21	NA
VCS.SC.M	0.74	0.78	0.82	0.98	1.25	1.75	14.11
VCS.SC.L	0.49	0.55	0.59	0.91	1.00	1.15	10.54
VCS.SC.I	0.64	0.80	1.18	2.07	2.42	27.19	NA
SVO.RC.M	1.31	2.64	4.34	4.50	11.60	NA	NA
SVO.SC.M	1.24	1.97	2.06	4.43	4.75	10.36	NA
SOC.RC.M	1.25	1.44	3.31	3.55	4.41	11.88	NA
HZO.RC.M	161.23	NA	NA	NA	NA	NA	NA
HZO.RC.L	83.78	NA	NA	NA	NA	NA	NA
HZO.SC.M	1.89	2.42	6.40	55.78	NA	NA	NA
HZO.SC.L	73.62	NA	NA	NA	NA	NA	NA
HCT.SC.M	0.48	0.69	0.88	2.24	2.42	3.08	12.26
HCT.SC.L	0.34	0.53	1.00	1.05	1.15	1.47	7.15
HCT.SC.I	0.88	2.39	4.28	27.99	NA	NA	NA
HCS.SC.M	0.50	1.64	2.54	4.28	7.43	34.05	NA
HCS.SC.L	0.26	0.58	0.86	1.36	2.57	14.98	NA
PD.SC.M	0.53	1.10	1.15	1.22	1.99	2.27	7.61
SOC.SC.M	1.03	1.12	1.24	2.35	2.49	2.99	7.42

* NA implies there are no associated CSLs.

8.4.3 Rebuttable Presumption Payback Period

Sections 325(o)(2)(B)(iii) and 345(e)(1)(A) of EPCA (42 U.S.C. 6295(o)(2)(B)(iii) and 42 U.S.C. 6316(e)(1)(A)) establish a rebuttable presumption for commercial refrigeration equipment. The rebuttable presumption states that a standard is economically justified if the 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." This rebuttable presumption test is an alternative path to establishing economic justification.

To evaluate the rebuttable presumption, DOE estimated the additional cost of purchasing more efficient, standards-compliant equipment, and compared this cost to the value of the energy saved during the first year of operation of the equipment. DOE interprets that the increased cost of purchasing standards-compliant equipment includes the cost of installing the equipment for use by the purchaser. DOE calculated the rebuttable presumption payback period (RPBP), or the ratio of the value of the increased installed price above the baseline efficiency level to the first year's energy cost savings. When RPBP is less than 3 years, the rebuttable presumption is satisfied; when RPBP is equal to or more than 3 years, the rebuttable presumption is not satisfied. Note that this RPBP calculation does not include other components to the annual operating cost of the equipment (*i.e.*, maintenance costs and repair costs). The RPBPs calculated can thus be different from the PBPs calculated in section 8.4.2.

DOE calculated the RPBPs for the distribution of installed costs and energy prices discussed in sections 8.4.1 and 8.4.2, which are representative of the same seven types of businesses and all 50 states. The RPBP was calculated for each CSL within each equipment class.

Table 8.4.7 shows the nationally averaged RPBPs calculated for all equipment classes and CSLs.

Table 8.4.7 Rebuttable Presumption Payback Periods by CSL and Equipment Class

Equipment Class	Median Rebuttable Presumption Payback Period* *years*						
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	1.66	1.68	3.39	3.52	10.62	NA	NA
VOP.RC.L	1.06	1.99	2.17	17.82	NA	NA	NA
VOP.SC.M	1.44	1.48	1.92	3.64	3.88	10.09	NA
VCT.RC.M	1.05	2.25	2.28	2.46	2.53	12.27	NA
VCT.RC.L	0.94	1.24	1.44	1.56	15.06	NA	NA
VCT.SC.M	0.79	1.62	2.08	2.15	2.34	2.38	7.63
VCT.SC.L	0.32	0.58	0.60	0.82	0.84	0.95	3.61
VCT.SC.I	0.71	0.81	1.53	1.63	1.85	12.41	NA
VCS.SC.M	0.66	0.70	0.74	0.88	1.10	1.56	12.72
VCS.SC.L	0.45	0.51	0.54	0.84	0.92	1.05	9.73
VCS.SC.I	0.58	0.74	1.07	1.90	2.17	25.18	NA
SVO.RC.M	1.24	2.53	3.83	3.97	10.27	NA	NA
SVO.SC.M	1.14	1.84	1.86	3.70	3.98	8.71	NA
SOC.RC.M	1.06	1.30	3.09	3.30	4.07	10.99	NA
HZO.RC.M	154.95	NA	NA	NA	NA	NA	NA
HZO.RC.L	80.51	NA	NA	NA	NA	NA	NA
HZO.SC.M	1.68	2.10	5.81	52.29	NA	NA	NA
HZO.SC.L	71.92	NA	NA	NA	NA	NA	NA
HCT.SC.M	0.45	0.63	0.79	2.02	2.15	2.75	10.98
HCT.SC.L	0.33	0.50	0.96	1.00	1.09	1.39	6.79
HCT.SC.I	0.84	2.08	3.92	26.54	NA	NA	NA
HCS.SC.M	0.48	1.47	2.17	3.39	6.22	30.01	NA
HCS.SC.L	0.25	0.55	0.79	1.23	2.35	13.99	NA
PD.SC.M	0.49	1.03	1.07	1.13	1.85	2.11	7.09
SOC.SC.M	0.80	0.91	1.00	2.04	2.16	2.59	6.44

* NA implies there are no associated CSLs.

8.5 DETAILED RESULTS

DOE presents detailed results from the LCC analysis in appendix 8B. Plots similar to Figure 8.4.2 and Figure 8.4.3 are presented in the appendix for all equipment classes. In addition, summary tables with all the necessary data in one table for each equipment class are presented in appendix 8B. Table 8.5.1 is a reproduction of the summary table for an example equipment class, VCT.SC.L. This table presents the mean values of installed costs, annual operating costs, LCC, LCC savings, and median values of PBP for all the CSLs. It also presents the distribution of customer impacts in the form of percentages of customers who experience net cost, no impact, and net benefit as compared to the base-case scenario. The average LCC savings and the percentage of customers experiencing a net benefit or cost are based on the market shares of the efficiency levels. In the base case, not all customers are assumed to be buying equipment at the baseline efficiency (Level 1). Some are assumed to be buying at higher efficiency levels. The LCC savings is an average of the savings achieved by customers who, in the base case, were buying less efficient equipment than the efficiency level examined. Customers with no impact were assumed in the base case to be already buying more efficient equipment, so the efficiency level in question would not affect them. Summary tables for each of the equipment classes are provided in appendix 8B.

Table 8.5.1 Summary of Results of LCC and PBP Analysis for VCT.SC.L Equipment Class

Efficiency Level	Energy Consumption *kWh/yr*	Mean Values of			Life-Cycle Cost Savings				Median Payback Period *years*
		Installed Cost *2012$*	Annual Operating Cost *2012$*	LCC *2012$*	Average Savings *2012$*	% of Customers that Experience*			
						Net Cost	No Impact	Net Benefit	
1	10,618	5,773	14,530	20,303	NA	NA	NA	NA	NA
2	7,852	5,861	11,345	17,205	3,037	0	90	10	0.31
3	4,921	6,101	8,222	14,323	4,186	0	76	24	0.58
4	4,853	6,120	8,150	14,270	2,523	0	60	40	0.61
5	4,541	6,271	7,811	14,082	1,984	0	44	56	0.83
6	4,514	6,286	7,790	14,076	1,587	3	29	68	0.85
7	4,411	6,364	7,692	14,056	1,343	7	15	78	0.96
8	4,222	8,077	7,486	15,562	(343)	74	2	24	3.65

* Percentages may not add up to 100 due to rounding.

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APPENDIX 8A. USER INSTRUCTIONS FOR LIFE-CYCLE COST SPREADSHEET

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APPENDIX 8A. USER INSTRUCTIONS FOR LIFE-CYCLE COST SPREADSHEET

8A.1 INTRODUCTION

Detailed results of the life-cycle cost (LCC) and payback period (PBP) analyses for commercial refrigeration equipment can be examined using a Microsoft Excel spreadsheet available on the U.S. Department of Energy's (DOE's) Building Technologies (BT) website at www.eere.energy.gov/buildings/appliance_standards/commercial_products.html.

8A.2 USER INSTRUCTIONS FOR LIFE-CYCLE COST SPREADSHEET

The spreadsheet allows the user to perform LCC analyses of any of 25 separate equipment classes of commercial refrigeration equipment. To fully execute the spreadsheet requires Microsoft Excel and Oracle's Crystal Ball software, both of which are commercially available.

The spreadsheet posted on the DOE website represents the latest version of the applicable model and has been developed and tested with Excel 2010 and with Crystal Ball, Fusion Edition, Release 11.1.2.1.000. Table 8A.2.1 describes the worksheets in the LCC spreadsheet.

Table 8A.2.1 Description of Worksheets in LCC Spreadsheet

Worksheet	Description
Summary	Contains the input selections and a summary table of energy use, operating costs, LCC, and payback.
Ranges	Provides the name, location, definition, and purpose of each of the named ranges in the LCC model.
CH Lifecycle vs Inst Cost	Provides a graph of the LCC versus installed cost by efficiency level for the selected equipment class.
CH Payback vs Inst Cost	Provides a graph of the simple PBP in years versus installed cost by efficiency level for the selected equipment class.
CB_Outputs	Stores Crystal Ball outputs. When Crystal Ball performs a 10,000-run analysis, it stores a large amount of data in active memory. At the end of the analysis, the spreadsheet captures (via formulas and a Visual Basic for Applications macro) statistical data from the Crystal Ball analyses. These data are stored in this worksheet.
Eq Distributions	Provides distributions for various inputs used by Crystal Ball during the Monte Carlo analyses.
OutputUS	Provides LCC and PBP output for all of the equipment classes, efficiency levels, and building types, but only for average U.S. conditions.
Equipment Parameters	Contains calculations of equipment purchase, maintenance and repair costs, and energy usage data used in the National Impact Analysis model.
Energy Expenditures	Summarizes energy expenditure data for all building types and all equipment classes. Data includes the 25 equipment classes currently being analyzed.
Engineering	Contains the per-unit manufacturer price data and energy use data for a standard-sized unit of equipment for each of the 25 equipment classes currently being analyzed. Also includes calculation of equipment price (including retail markups and the sales tax), the installation price, and the repair and maintenance costs per unit.

Table 8A.2.1 (cont)

Worksheet	Description
Markups and Market	Calculates the wholesale and retail markup for the selected equipment class, including any state and local sales tax. Also calculates weighted average sales tax rates and weighted average contractor's markup. Contains data on maintenance and repair costs and market channels.
Contractor Markup Index	Contains data on contractor markups by state for calculating state-level overall wholesale and retail markups.
Building Energy	Captures the per-unit energy usage for a standard-sized unit of equipment in each equipment class, efficiency level, and state in kilowatt-hours and million British thermal units.
AEO2013 Projections	Contains projections of future energy prices and price indices from the 2013 *Annual Energy Outlook* (*AEO2013*). Also contains estimates of commercial sector energy prices by state, and an index of energy prices by business type relative to the commercial average.
Electricity Prices Ratios CBECS	Contains data from the 2003 *Commercial Building Energy Consumption Survey* (CBECS) on electricity prices paid by selected business types.
State Energy Price Detail	Contains data on prices paid for energy by commercial sector customers from the Energy Information Administration (EIA) Form EIA-826 Database, "Sales and revenue data by state, monthly back to 1990 (Form EIA-826)," for 2012, together with calculations to estimate the 2012 prices.
Installation Cost by State	Contains multipliers to vary the installation cost by state. Derived from data published by RS Means Construction Publishers & Consultants, Kingston, MA.
Discount Rate	Contains data from which an average discount rate and a distribution of discount rates are determined using weighted average cost of capital derived from data on individual firms published at the Damodaran Online website.
Sales Tax	Contains data on sales tax rates by state and population data by state. Also contains census data on sales of refrigerated and frozen food by state for food sales. Calculates population weights for all business types, and shipment weights for the four business types with available food shipment data (supermarkets, convenience stores and small specialty stores, convenience stores with gas pumps, and large multi-line retailers). Contains a selection of the weights to be used for each state for calculating weighted average national values. Currently uses population weighting given the lack of food shipment information for foodservice building types.
GDP Deflator	Contains Gross Domestic Product Implicit Price Deflators (GDP Deflators) from the *AEO2013* database. The primary use of the data is inflating to 2012 dollars.
Lifetime	Contains the estimated average commercial refrigeration equipment lifetime in years.
Labels	Used as an interface between user inputs and the rest of the worksheets — do not modify this sheet

Basic instructions for operating the LCC spreadsheets are as follows:

1. Once you have downloaded the LCC file from the DOE BT website, open the file using Excel. Select Yes when asked if you want to enable macros. Select No when asked if you want to update data. At the bottom of the Excel window, click the tab for the Summary sheet. Note that if you plan to run the Monte Carlo routine, you must have Crystal Ball loaded as an add-in and activated.

2. Use Excel's View/Zoom commands at the top menu bar to size the display to your monitor.

3. You can interact with the spreadsheet by clicking choices or entering data using the graphical interface on the Summary tab. Select from the inputs listed under the User Options heading.

4. Under the User Defined Inputs heading, select from the buttons and boxes for the following: (1) energy price projection; (2) start year; (3) region (state); (4) equipment family; (5) equipment operating mode; (6) rating temperature; (7) baseline efficiency level; (8) selected efficiency level; (9) building type; (10) analysis type; (11) installation options; (12) installation cost projection; and (13) repair cost projection. If you are investigating the impacts of reducing first costs (*e.g.*, by a tax credit), enter percentage reductions at each efficiency level affected. The default calculation is a single sample case, which runs almost instantaneously. You can run all cases for U.S. average conditions by clicking All US Cases. You can start a complete Crystal Ball simulation by clicking the Monte Carlo button. While there is no macro button, you can run all cases for all states by running the macro on the Developer tab titled AllRunner_15. To change inputs listed under User Defined Inputs, select the input you wish to change by either clicking the appropriate button or selecting the appropriate input from the input box.

    a. Equipment classes are defined as particular combinations of equipment families, operating modes, and rating temperatures. Because there are ten potential equipment families, two potential operating modes (remote and self contained), and three possible temperature ratings provided, there are 60 potential equipment classes that could be analyzed. If you select a combination of equipment family, operating mode, and temperature ranges that results in a potential equipment class that has not been analyzed by DOE (because few or no shipments have been identified), the Annual Electricity Bill shown on the Summary tab will be $0 per year and the cells containing those data will turn red and will be cross-hatched out. In addition, there will be a blue background note on the summary tab that reads "Not an Analyzed Equipment Class." If data exist for the equipment class, the note will read "Equipment Class O.K." If the All US Cases option is run, the last case is not an analyzed equipment class, so the note panel will read "Not an Analyzed Equipment Class" at the conclusion of the run.

    b. There are up to eight possible efficiency levels. If an equipment class contains fewer than eight levels, the extra levels will be shown as #NA in the Total Installed Price column on the Summary tab.

    c. A new discount rate or lifetime can also be entered if a value other than the default value or default distribution is wanted; however, this will overwrite the existing formula. As a result, DOE does not recommend saving the spreadsheet after the code is changed. The default discount rate can be changed by going to the Discount Rate tab and changing the default values in cells C4 through C10. A different lifetime can be selected by going to the Lifetime tab and entering a different value in the white box at cell D3.

5. This spreadsheet gives the user three types of calculation methods:

    a. If nothing is selected for a calculation method (Sample Calculation), then all calculations are performed for a set of single input values, usually an average. The new results are shown on the Summary tab as soon as the new input values are entered.

    b. Alternatively, if the Monte Carlo button is clicked, the spreadsheet generates a set of results from calculations for each equipment family, equipment operating mode, and rating temperature (which together define an equipment class). For a number of inputs, the Crystal Ball software has custom distributions that it uses to set the level of the input. The model runs each of the studied classes in turn, performing 10,000 model runs for each. At the end of each equipment class run, the model records to the CB_Outputs worksheet a large number of outputs that you can then use for further analyses. The Monte Carlo button executes a macro written in Visual Basic for Applications to loop through all equipment classes and selected efficiency levels. The Monte Carlo analysis takes as little as 8 hours on a powerful desktop computer with four processors and as long as 15 hours on a new, powerful but compact, laptop computer. In short, if you run the Monte Carlo analysis, have a backup computer available.

    c. The third alternative, All US Cases, runs each equipment class for each building type and efficiency level only at U.S. average prices, markups, etc. This option produces the required output file to run the National Energy Savings/National Impact Assessment spreadsheet.

APPENDIX 8B. DETAILED LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS RESULTS

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APPENDIX 8B. DETAILED LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS RESULTS

8B.1 INTRODUCTION

This appendix contains detailed output from the life-cycle cost (LCC) analysis for commercial refrigeration equipment using the LCC spreadsheet. LCC and payback periods (PBPs) are presented for each of the 25 product classes at each efficiency level. See chapter 8 of the technical support document for an explanation of the LCC spreadsheet.

LCC savings output obtained from the LCC analysis are in the form of distributions. LCC savings distributions were generated by performing 10,000 separate simulations using the LCC spreadsheet, and allowing the spreadsheet to select values for numerous inputs given probability distributions for each input. Given the results of the LCC model simulations for each equipment type, the U.S. Department of Energy (DOE) calculated summary statistics—average values for the LCC, product installation costs, and operating costs for a distribution of customers who: (1) receive benefits in the form of lower LCC results; (2) are not affected by the standards; or (3) experience a cost in the form of increased LCC from equipment ownership. Results of the LCC and accompanying PBP analyses are shown in the tables in this appendix.

Also included in this appendix are two graphical presentations for each of the LCC and PBP results. One of these presentations plots the LCC savings distribution for all equipment classes analyzed. The figures illustrate the mean and median values on the plot with the help of red and blue markers, respectively. Additionally, the mean and median values are surrounded by rectangular boxes used to represent the 25th and 75th percentile values. The lower edge of the elongated rectangle represents the 25th percentile, which means that 25 percent of the customers will experience LCC savings below the value represented by the bottom of the rectangle if the standard were set at the level in question. The upper edge of the elongated rectangle represents the 75th percentile. Finally, each of the rectangles includes two "tails," or two vertical black lines, extending downward to represent the 5th percentile (lower end) and upward to represent the 95th percentile (upper end).

The remainder of this appendix presents the tabular and graphical results for each of the 25 equipment classes analyzed for the commercial refrigeration equipment rulemaking.

8B.2 LCC RESULTS

8B.2.1 Life-Cycle Cost Results for Vertical Open, Remote Condensing, Medium Temperature (VOP.RC.M)

Table 8B.2.1 LCC Results for Vertical Open, Remote Condensing, Medium Temperature (VOP.RC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	% of Customers that Experience: Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	17,438	9,437	20,911	30,348	NA	NA	NA	NA	NA
2	17,095	9,490	20,618	30,108	236	0	76	24	1.73
3	16,180	9,633	19,849	29,482	743	0	52	48	1.77
4	13,033	10,823	17,364	28,187	1,789	0	28	72	3.77
5	12,962	10,898	17,303	28,201	1,494	11	15	74	3.91
6	12,798	14,006	17,162	31,168	(1,669)	90	2	8	11.76
7	12,798	NA	NA	NA	NA	NA	NA	NA	NA
8	12,798	NA	NA	NA	NA	NA	NA	NA	NA

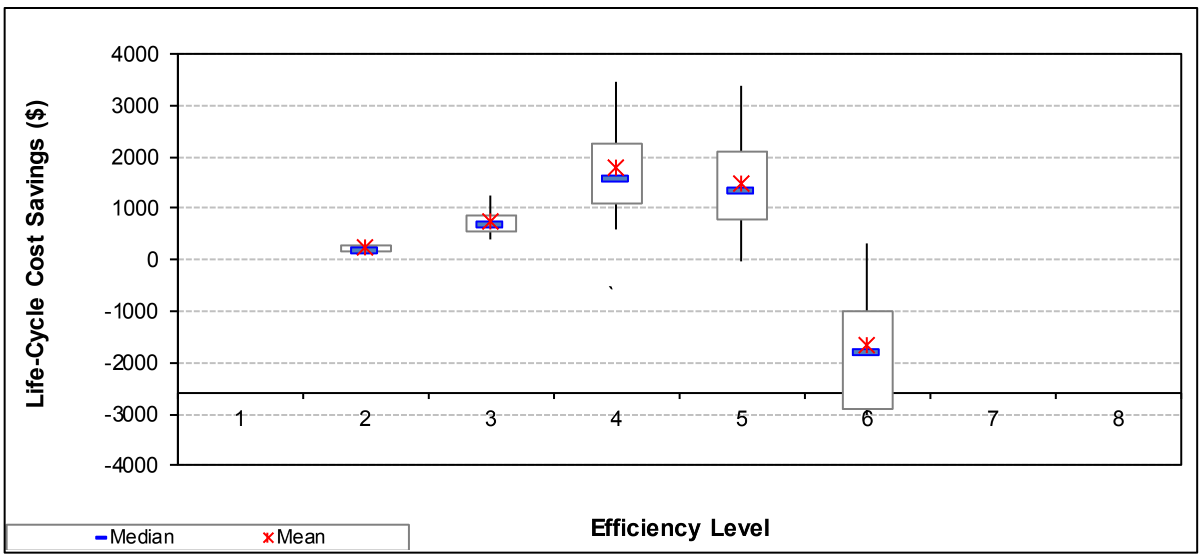

Figure 8B.2.1 LCC Savings Statistical Results for Vertical Open, Remote Condensing, Medium Temperature (VOP.RC.M)

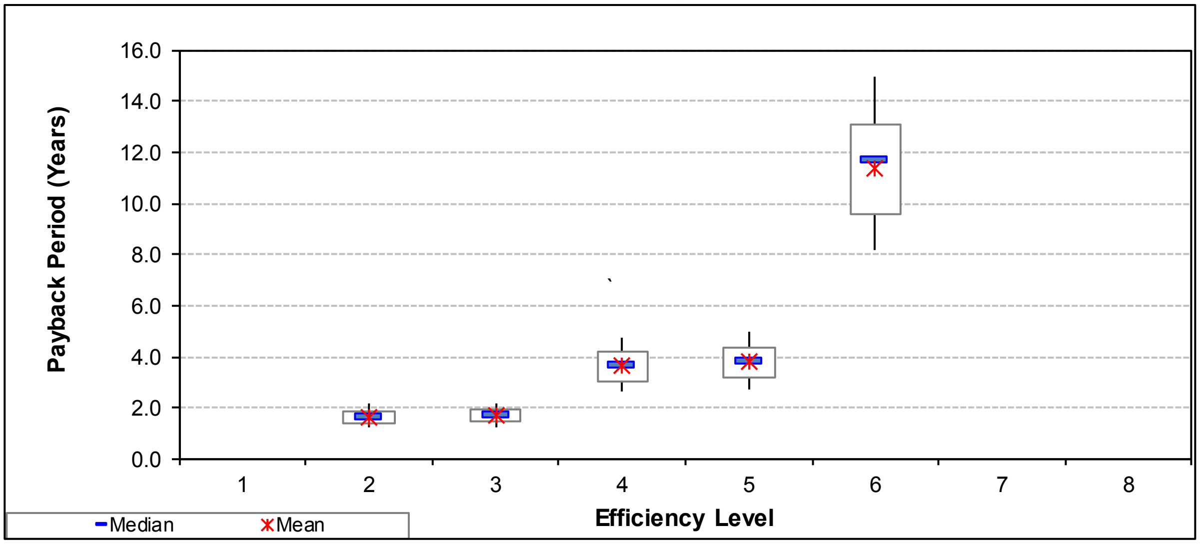

Figure 8B.2.2 PBP Statistical Results for Vertical Open, Remote Condensing, Medium Temperature (VOP.RC.M)

8B.2.2 Life-Cycle Cost Results for Vertical Open, Remote Condensing, Low Temperature (VOP.RC.L)

Table 8B.2.2 LCC Results for Vertical Open, Remote Condensing, Low Temperature (VOP.RC.L)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers: Installed Cost (2012$)	Life-Cycle Cost, All Customers: Total Discounted Operating Cost (2012$)	Life-Cycle Cost, All Customers: LCC, All Customers (2012$)	Life-Cycle Cost Savings: Affected Customers' Average Savings (2012$)	% of Customers that Experience: Net Cost (%)	% of Customers that Experience: No Impact (%)	% of Customers that Experience: Net Benefit (%)	Payback Period, Median (Years)
1	39,503	10,027	39,803	49,830	NA	NA	NA	NA	NA
2	38,770	10,099	39,184	49,282	537	0	74	26	1.11
3	36,877	10,511	37,520	48,031	1,517	0	48	52	2.03
4	36,685	10,594	37,356	47,950	1,130	0	25	75	2.22
5	36,088	15,667	36,847	52,513	(3,693)	98	2	0	18.30
6	36,088	NA	NA	NA	NA	NA	NA	NA	NA
7	36,088	NA	NA	NA	NA	NA	NA	NA	NA
8	36,088	NA	NA	NA	NA	NA	NA	NA	NA

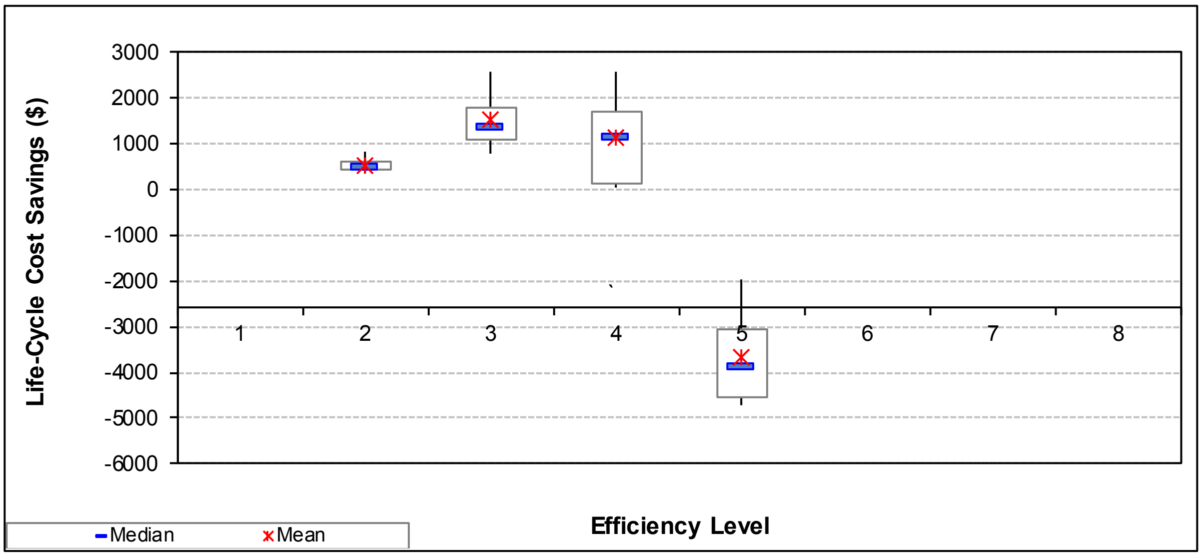

Figure 8B.2.3 LCC Savings Statistical Results for Vertical Open, Remote Condensing, Low Temperature (VOP.RC.L)

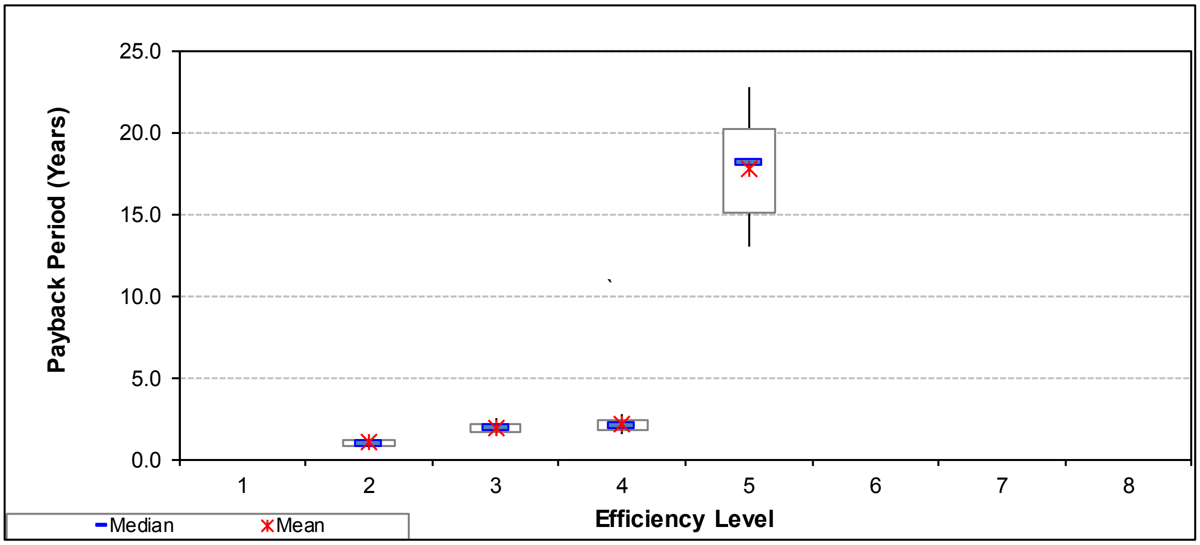

Figure 8B.2.4 PBP Statistical Results for Vertical Open, Remote Condensing, Low Temperature (VOP.RC.L)

8B.2.3 Life-Cycle Cost Results for Vertical Open, Self-Contained, Medium Temperature (VOP.SC.M)

Table 8B.2.3 LCC Results for Vertical Open, Self-Contained, Medium Temperature (VOP.SC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	% of Customers that Experience			
						Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	11,201	4,611	15,740	20,351	NA	NA	NA	NA	NA
2	11,085	4,629	15,605	20,234	116	0	81	19	1.50
3	10,960	4,650	15,471	20,120	171	0	62	38	1.61
4	10,804	4,693	15,314	20,008	227	0	43	57	2.17
5	9,747	5,183	14,180	19,364	815	0	25	75	4.12
6	9,718	5,234	14,147	19,381	691	11	14	75	4.39
7	9,660	6,293	14,079	20,373	(377)	77	3	20	11.37
8	9,660	NA	NA	NA	NA	NA	NA	NA	NA

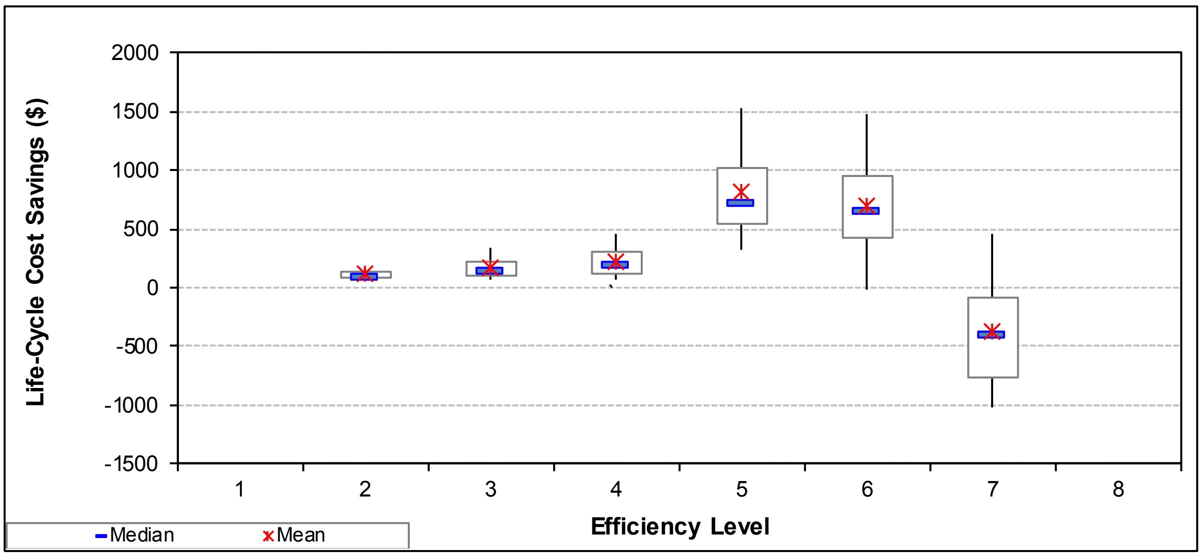

Figure 8B.2.5 LCC Savings Statistical Results for Vertical Open, Self-Contained, Medium Temperature (VOP.SC.M)

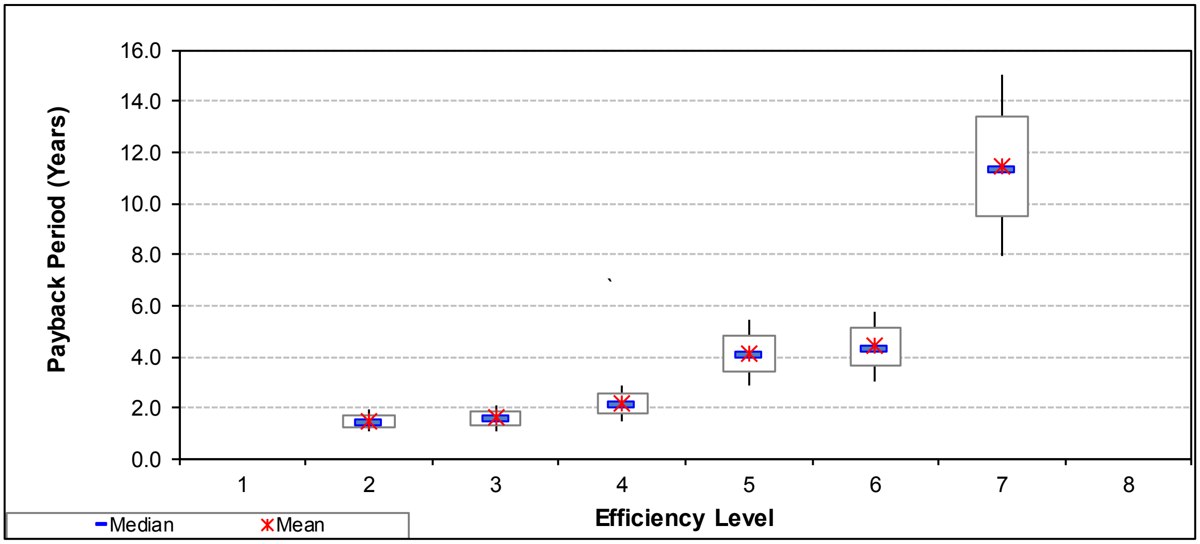

Figure 8B.2.6 PBP Statistical Results for Vertical Open, Self-Contained, Medium Temperature (VOP.SC.M)

8B.2.4 Life-Cycle Cost Results for Vertical Closed Transparent, Remote Condensing, Medium Temperature (VCT.RC.M)

Table 8B.2.4 LCC Results for Vertical Closed Transparent, Remote Condensing, Medium Temperature (VCT.RC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers: Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Life-Cycle Cost Savings: Affected Customers' Average Savings (2012$)	% of Customers that Experience: Net Cost (%)	No Impact (%)	Net Benefit (%)	Payback Period, Median (Years)
1	5,931	12,045	12,003	24,048	NA	NA	NA	NA	NA
2	5,679	12,070	11,800	23,870	175	0	81	19	1.23
3	2,955	12,669	9,411	22,081	1,864	0	62	38	2.42
4	2,285	12,819	8,809	21,629	1,759	0	46	54	2.43
5	2,195	12,900	8,729	21,629	1,364	9	31	60	2.62
6	2,177	12,929	8,715	21,644	1,108	26	16	57	2.70
7	2,005	16,537	8,560	25,097	(2,509)	94	2	4	13.09
8	2,005	NA	NA	NA	NA	NA	NA	NA	NA

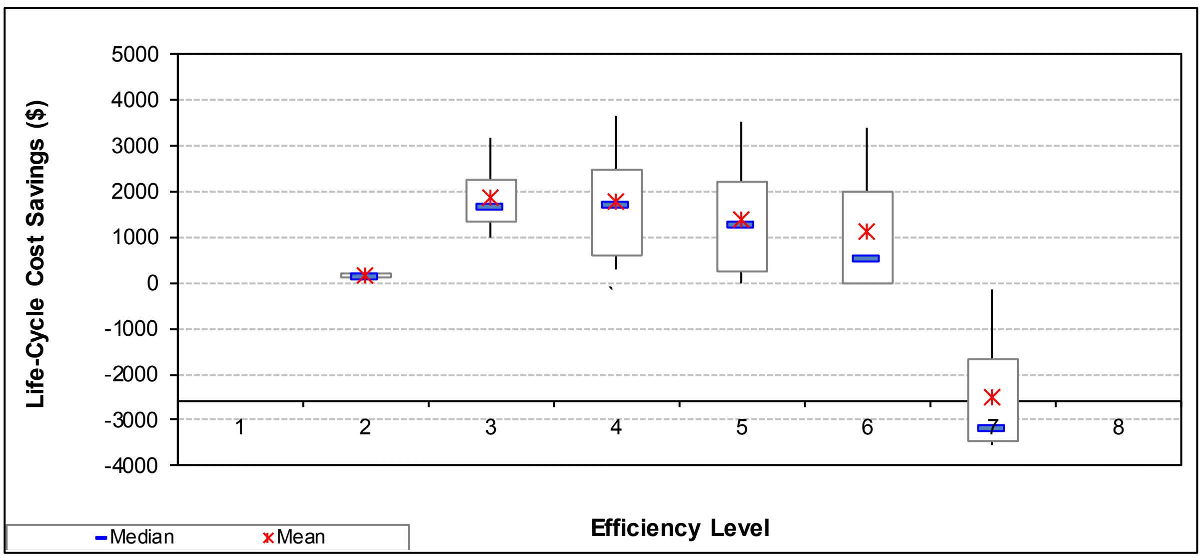

Figure 8B.2.7 LCC Savings Statistical Results for Vertical Closed Transparent, Remote Condensing, Medium Temperature (VCT.RC.M)

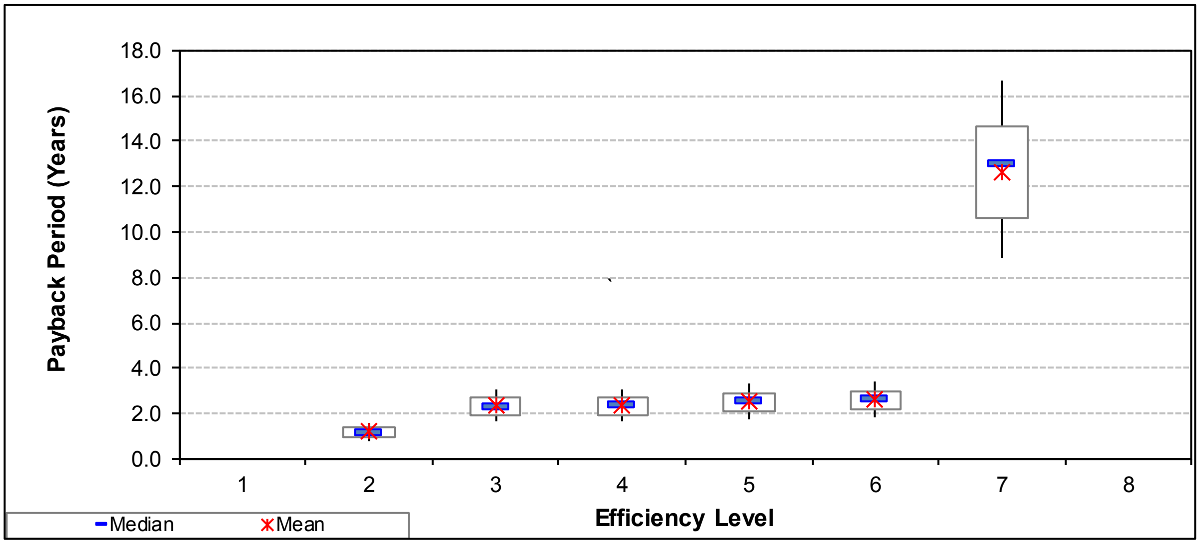

Figure 8B.2.8 PBP Statistical Results for Vertical Closed Transparent, Remote Condensing, Medium Temperature (VCT.RC.M)

8B.2.5 Life-Cycle Cost Results for Vertical Closed Transparent, Remote Condensing, Low Temperature (VCT.RC.L)

Table 8B.2.5 LCC Results for Vertical Closed Transparent, Remote Condensing, Low Temperature (VCT.RC.L)

		Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				
						% of Customers that Experience			
Efficiency Level Number	Efficiency Level (kWh/yr)	Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	Net Cost (%)	No Impact (%)	Net Benefit (%)	Payback Period, Median (Years)
1	14,239	13,423	20,148	33,571	NA	NA	NA	NA	NA
2	12,144	13,606	18,284	31,890	1,659	0	81	19	0.98
3	11,362	13,756	17,581	31,337	1,357	0	60	40	1.30
4	11,161	13,836	17,401	31,237	1,005	0	40	60	1.51
5	11,056	13,887	17,311	31,198	798	0	21	79	1.64
6	10,531	18,626	16,840	35,466	(3,624)	97	2	1	15.75
7	10,531	NA	NA	NA	NA	NA	NA	NA	NA
8	10,531	NA	NA	NA	NA	NA	NA	NA	NA

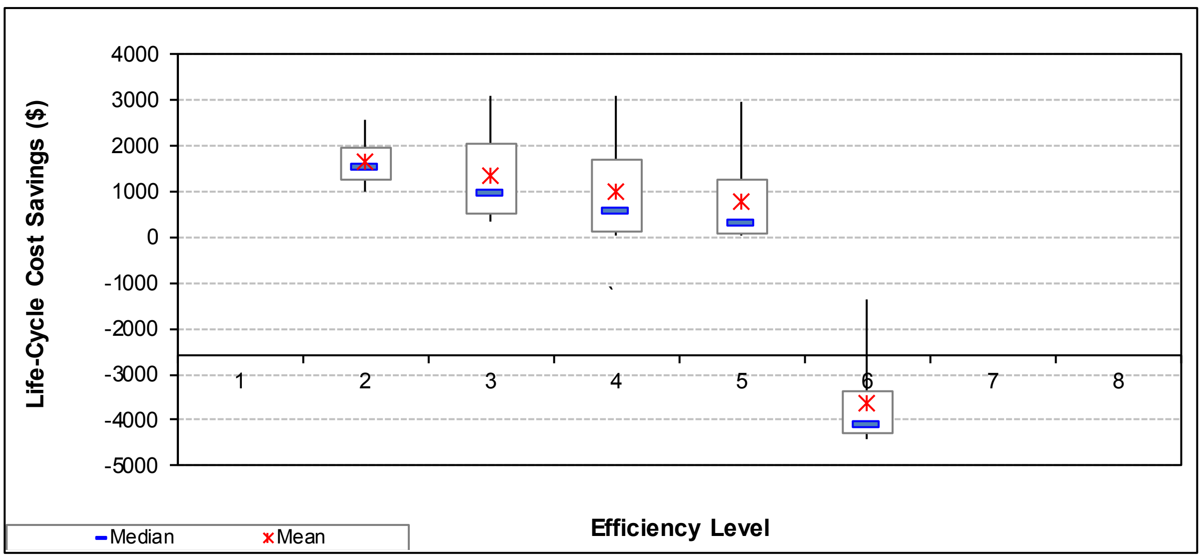

Figure 8B.2.9 LCC Savings Statistical Results for Vertical Closed Transparent, Remote Condensing, Low Temperature (VCT.RC.L)

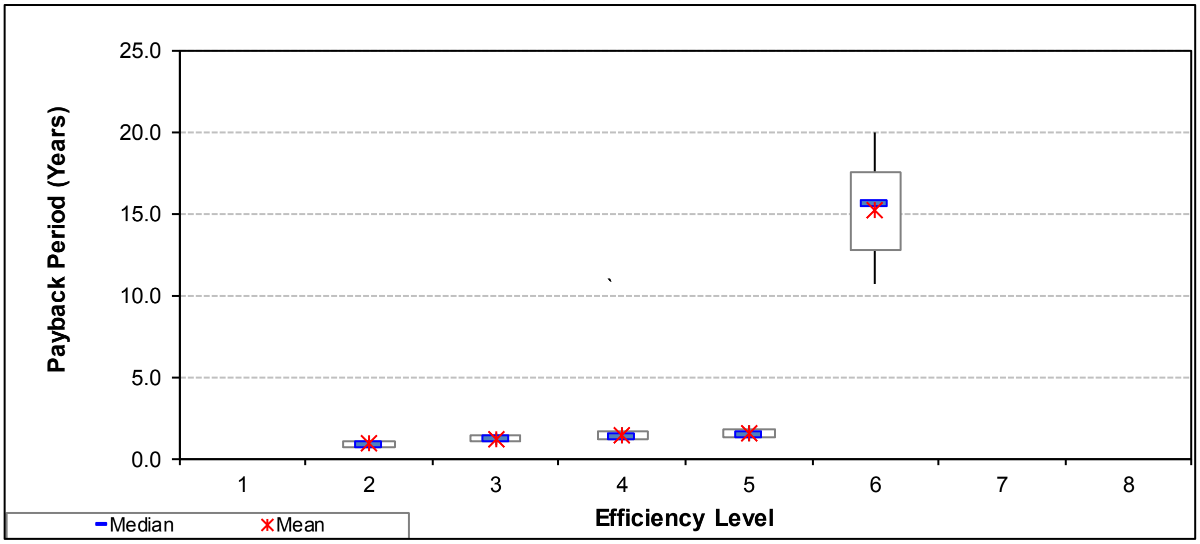

Figure 8B.2.10 PBP Statistical Results for Vertical Closed Transparent, Remote Condensing, Low Temperature (VCT.RC.L)

8B.2.6 Life-Cycle Cost Results for Vertical Closed Transparent, Self-Contained, Medium Temperature (VCT.SC.M)

Table 8B.2.6 LCC Results for Vertical Closed Transparent, Self-Contained, Medium Temperature (VCT.SC.M)

		Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				
						% of Customers that Experience			
Efficiency Level Number	Efficiency Level (kWh/yr)	Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	Net Cost (%)	No Impact (%)	Net Benefit (%)	Payback Period, Median (Years)
1	3,365	4,546	5,884	10,430	NA	NA	NA	NA	NA
2	2,758	4,594	5,261	9,855	566	0	83	17	0.86
3	1,488	4,849	3,916	8,764	1,364	0	66	34	1.73
4	1,182	4,999	3,583	8,582	1,122	0	51	49	2.21
5	1,141	5,024	3,552	8,576	894	4	38	58	2.30
6	1,088	5,077	3,495	8,571	748	11	25	64	2.49
7	1,082	5,088	3,489	8,578	641	27	13	60	2.54
8	979	6,362	3,377	9,739	(596)	74	2	24	8.13

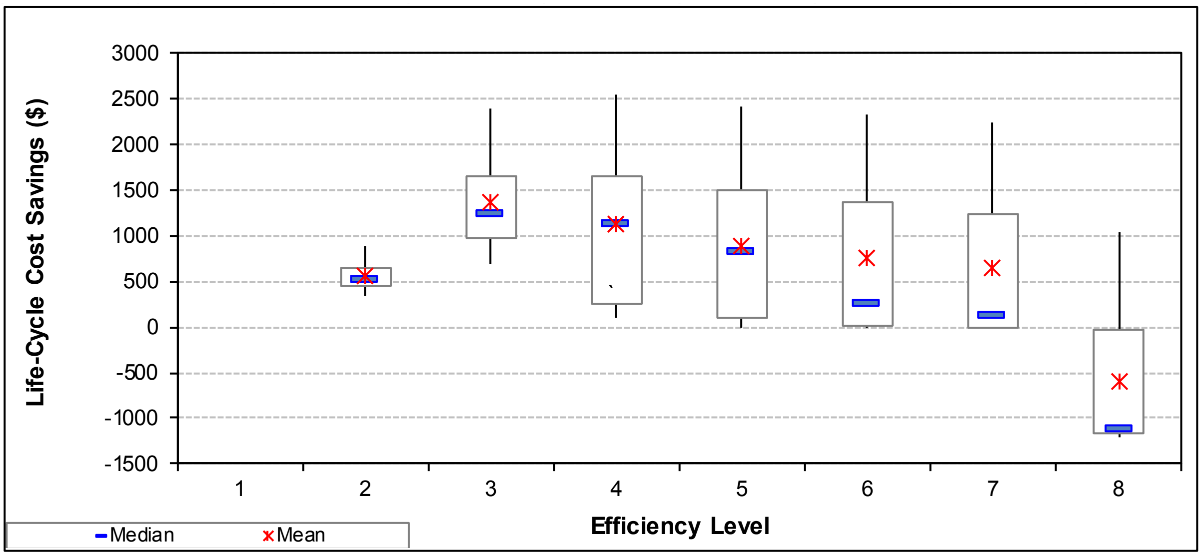

Figure 8B.2.11 LCC Savings Statistical Results for Vertical Closed Transparent, Self-Contained, Medium Temperature (VCT.SC.M)

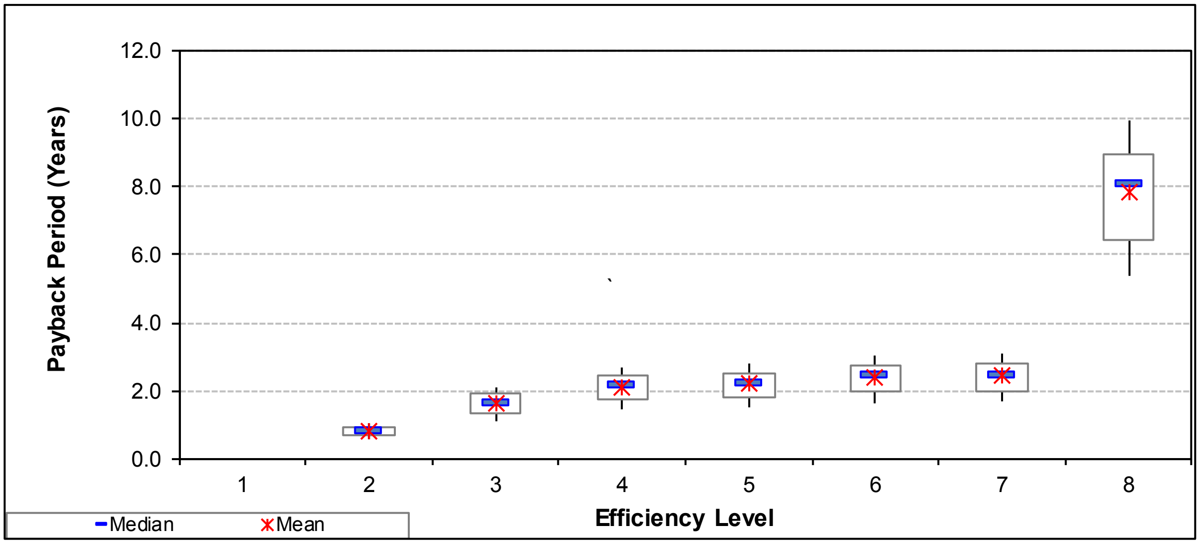

Figure 8B.2.12 PBP Statistical Results for Vertical Closed Transparent, Self-Contained, Medium Temperature (VCT.SC.M)

8B.2.7 Life-Cycle Cost Results for Vertical Closed Transparent, Self-Contained, Low Temperature (VCT.SC.L)

Table 8B.2.7 LCC Results for Vertical Closed Transparent, Self-Contained, Low Temperature (VCT.SC.L)

		Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				
						% of Customers that Experience			
Efficiency Level Number	Efficiency Level (kWh/yr)	Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	Net Cost (%)	No Impact (%)	Net Benefit (%)	Payback Period, Median (Years)
1	10,618	5,773	14,530	20,303	NA	NA	NA	NA	NA
2	7,852	5,861	11,345	17,205	3,037	0	90	10	0.31
3	4,921	6,101	8,222	14,323	4,186	0	76	24	0.58
4	4,853	6,120	8,150	14,270	2,523	0	60	40	0.61
5	4,541	6,271	7,811	14,082	1,984	0	44	56	0.83
6	4,514	6,286	7,790	14,076	1,587	3	29	68	0.85
7	4,411	6,364	7,692	14,056	1,343	7	15	78	0.96
8	4,222	8,077	7,486	15,562	(343)	74	2	24	3.65

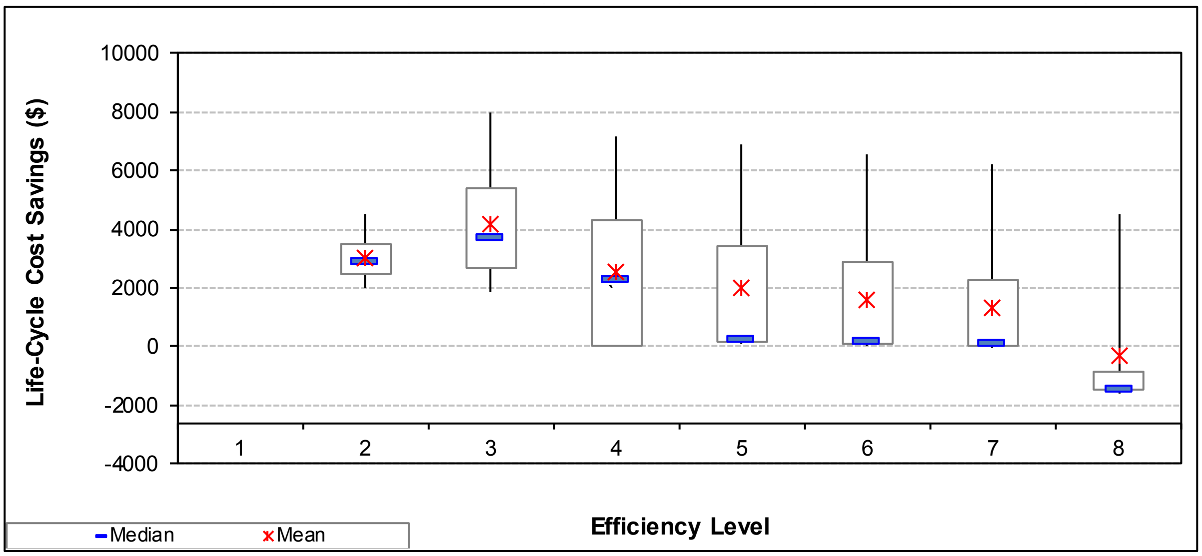

Figure 8B.2.13 LCC Savings Statistical Results for Vertical Closed Transparent, Self-Contained, Low Temperature (VCT.SC.L)

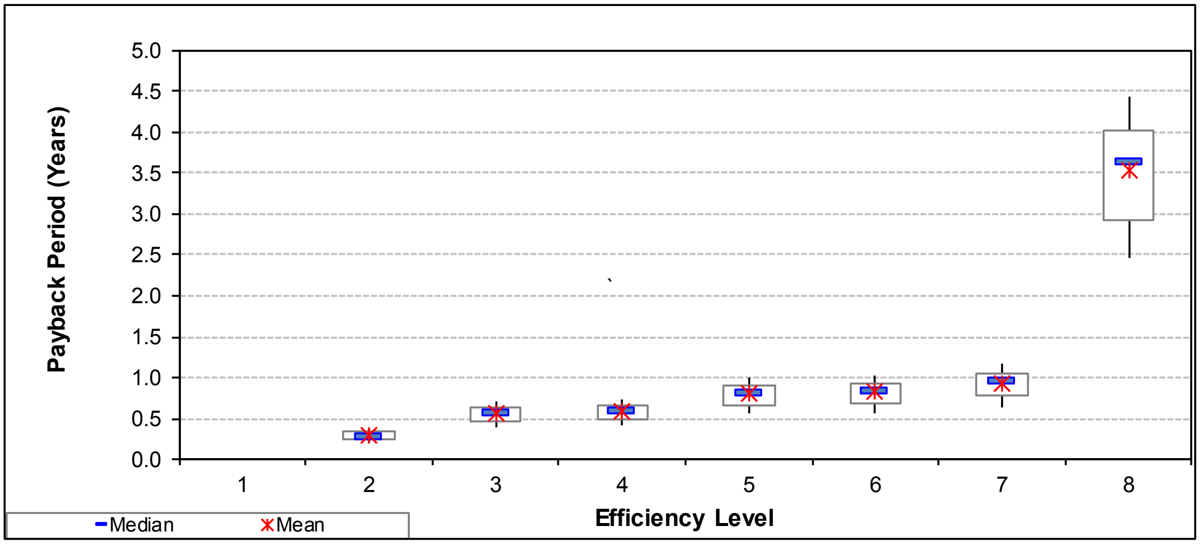

Figure 8B.2.14 PBP Statistical Results for Vertical Closed Transparent, Self-Contained, Low Temperature (VCT.SC.L)

8B.2.8 Life-Cycle Cost Results for Vertical Closed Transparent, Self-Contained, Ice-Cream Temperature (VCT.SC.I)

Table 8B.2.8 LCC Results for Vertical Closed Transparent, Self-Contained, Ice-Cream Temperature (VCT.SC.I)

		Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				
						% of Customers that Experience			
Efficiency Level Number	Efficiency Level (kWh/yr)	Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	Net Cost (%)	No Impact (%)	Net Benefit (%)	Payback Period, Median (Years)
1	7,559	6,280	11,456	17,736	NA	NA	NA	NA	NA
2	6,414	6,368	10,200	16,567	1,152	0	84	16	0.75
3	6,370	6,383	10,160	16,543	572	0	65	35	0.86
4	6,024	6,533	9,778	16,311	608	0	48	52	1.63
5	5,972	6,558	9,733	16,292	486	1	32	68	1.74
6	5,891	6,612	9,644	16,256	432	1	16	83	1.97
7	5,609	8,883	9,332	18,215	(1,592)	95	1	3	13.21
8	5,609	NA	NA	NA	NA	NA	NA	NA	NA

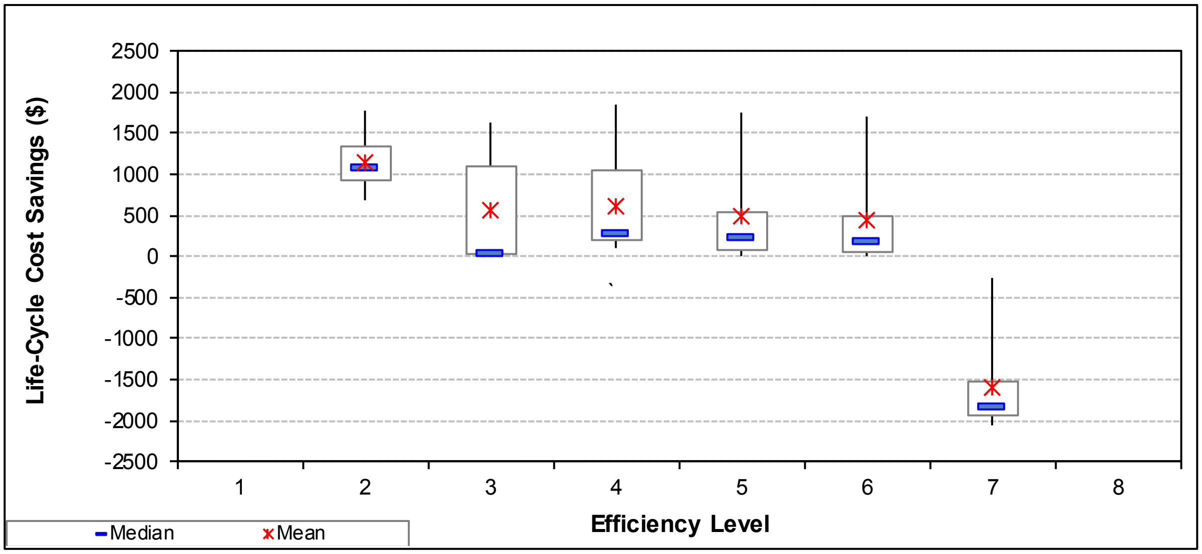

Figure 8B.2.15 LCC Savings Statistical Results for Vertical Closed Transparent, Self-Contained, Ice-Cream Temperature (VCT.SC.I)

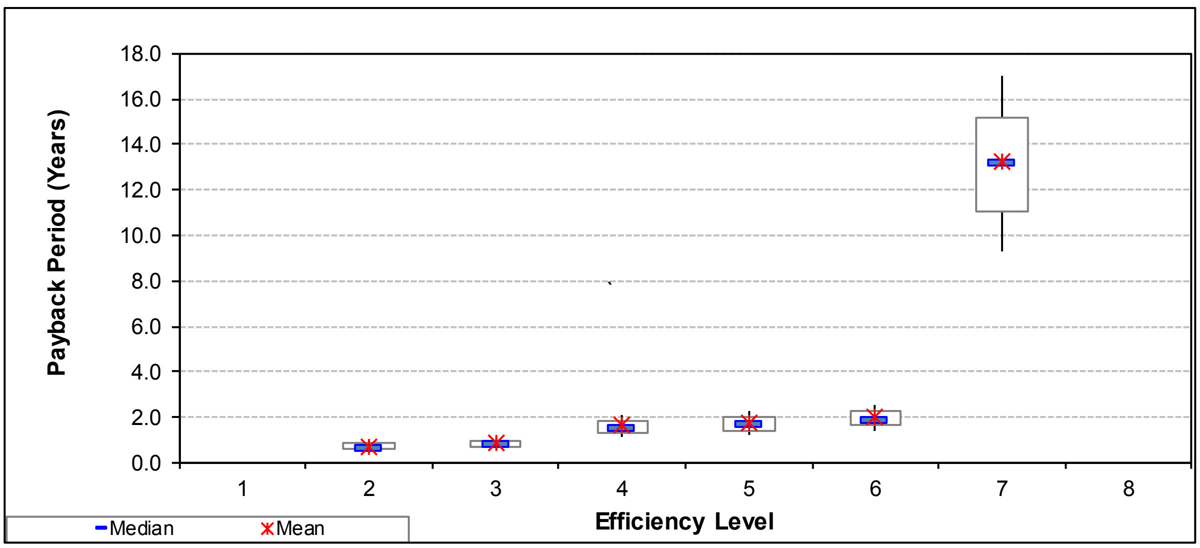

Figure 8B.2.16 PBP Statistical Results for Vertical Closed Transparent, Self-Contained, Ice-Cream Temperature (VCT.SC.I)

8B.2.9 Life-Cycle Cost Results for Vertical Closed Solid, Self-Contained, Medium Temperature (VCS.SC.M)

Table 8B.2.9 LCC Results for Vertical Closed Solid, Self-Contained, Medium Temperature (VCS.SC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	% of Customers that Experience			
						Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	1,625	3,332	2,733	6,065	NA	NA	NA	NA	NA
2	923	3,379	2,171	5,550	508	0	87	13	0.74
3	863	3,386	2,122	5,508	279	0	72	28	0.78
4	840	3,390	2,104	5,494	196	0	57	43	0.82
5	793	3,406	2,070	5,476	163	0	42	58	0.98
6	735	3,431	2,031	5,462	144	1	27	72	1.25
7	659	3,484	1,967	5,451	132	7	13	80	1.75
8	507	4,771	1,837	6,608	(1,042)	99	1	0	14.11

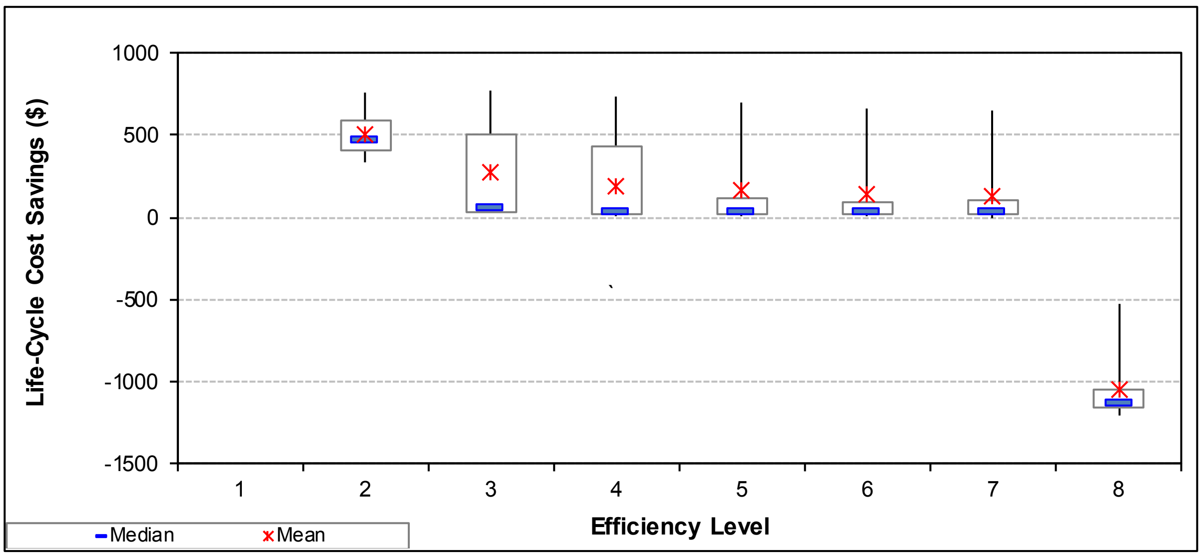

Figure 8B.2.17 LCC Savings Statistical Results for Vertical Closed Solid, Self-Contained, Medium Temperature (VCS.SC.M)

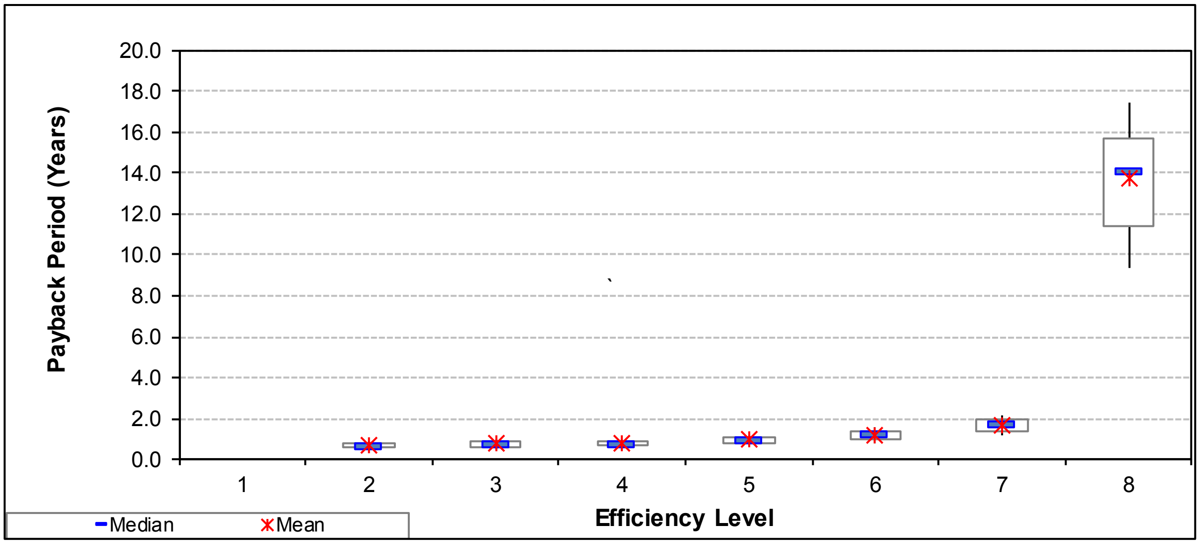

Figure 8B.2.18 PBP Statistical Results for Vertical Closed Solid, Self-Contained, Medium Temperature (VCS.SC.M)

8B.2.10 Life-Cycle Cost Results for Vertical Closed Solid, Self-Contained, Low Temperature (VCS.SC.L)

Table 8B.2.10 LCC Results for Vertical Closed Solid, Self-Contained, Low Temperature (VCS.SC.L)

		Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				
						% of Customers that Experience			
Efficiency Level Number	Efficiency Level (kWh/yr)	Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	Net Cost (%)	No Impact (%)	Net Benefit (%)	Payback Period, Median (Years)
1	4,014	3,603	4,947	8,549	NA	NA	NA	NA	NA
2	2,808	3,658	3,957	7,615	924	0	88	12	0.49
3	2,649	3,673	3,829	7,501	525	0	73	27	0.55
4	2,582	3,682	3,772	7,454	382	0	58	43	0.59
5	2,463	3,735	3,671	7,405	329	0	42	58	0.91
6	2,432	3,751	3,651	7,402	268	5	28	68	1.00
7	2,394	3,776	3,630	7,405	221	20	14	66	1.15
8	2,084	5,505	3,366	8,871	(1,274)	97	1	2	10.54

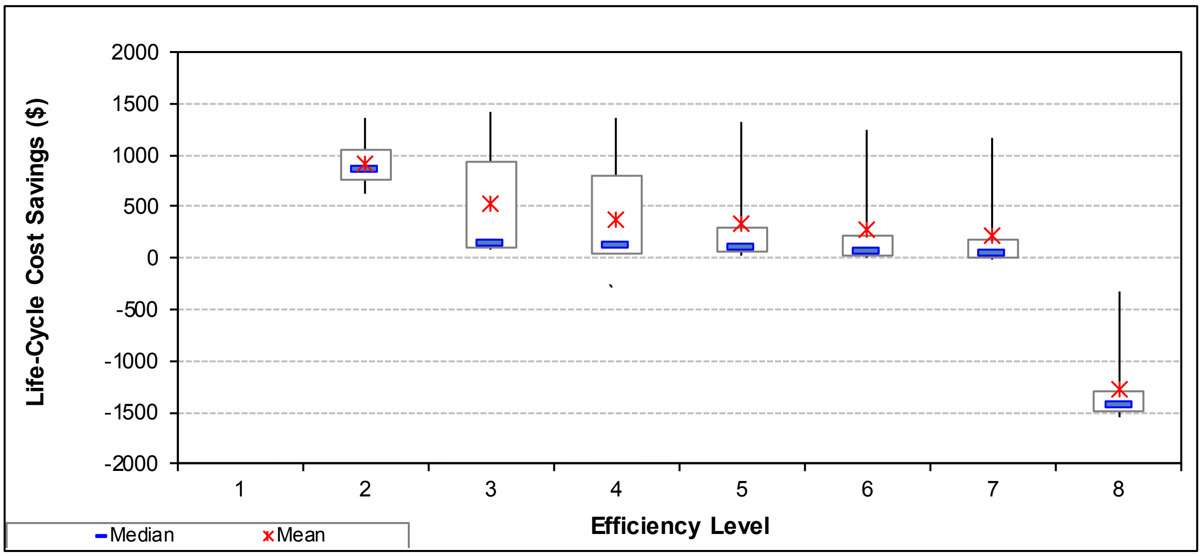

Figure 8B.2.19 LCC Savings Statistical Results for Vertical Closed Solid, Self-Contained, Low Temperature (VCS.SC.L)

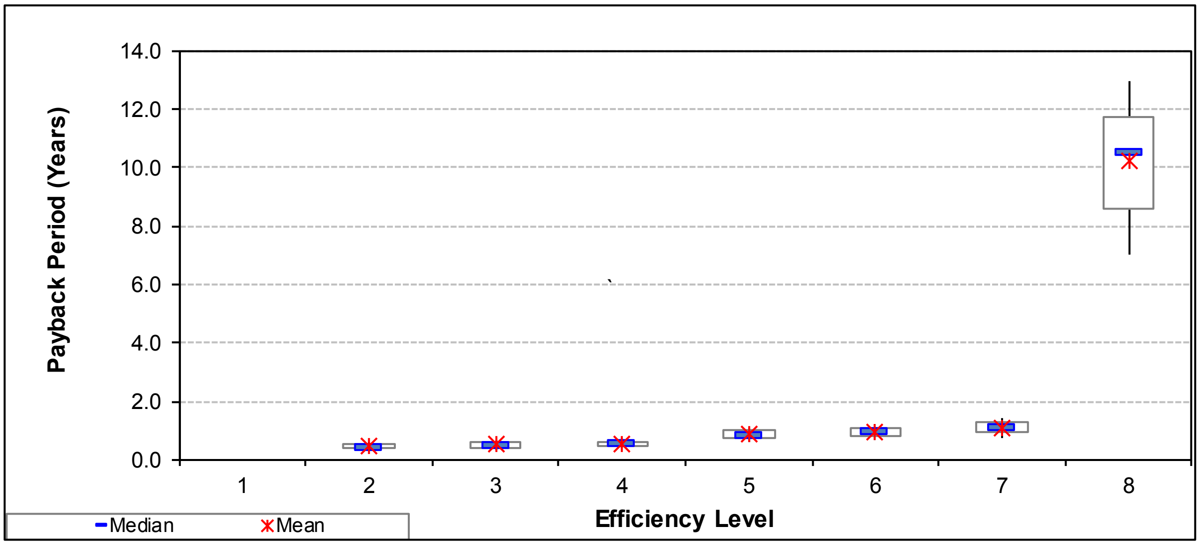

Figure 8B.2.20 PBP Statistical Results for Vertical Closed Solid, Self-Contained, Low Temperature (VCS.SC.L)

8B.2.11 Life-Cycle Cost Results for Vertical Closed Solid, Self-Contained, Ice-Cream Temperature (VCS.SC.I)

Table 8B.2.11 LCC Results for Vertical Closed Solid, Self-Contained, Ice-Cream Temperature (VCS.SC.I)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	% of Customers that Experience: Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	6,979	4,124	7,790	11,913	NA	NA	NA	NA	NA
2	6,969	4,124	7,782	11,906	7	0	83	17	0.64
3	6,657	4,148	7,526	11,674	237	0	67	33	0.80
4	6,612	4,164	7,494	11,658	172	0	49	51	1.18
5	6,492	4,218	7,392	11,610	177	0	32	68	2.07
6	6,438	4,243	7,357	11,600	153	3	16	81	2.42
7	6,034	6,535	7,013	13,548	(1,819)	99	1	0	27.19
8	6,034	NA	NA	NA	NA	NA	NA	NA	NA

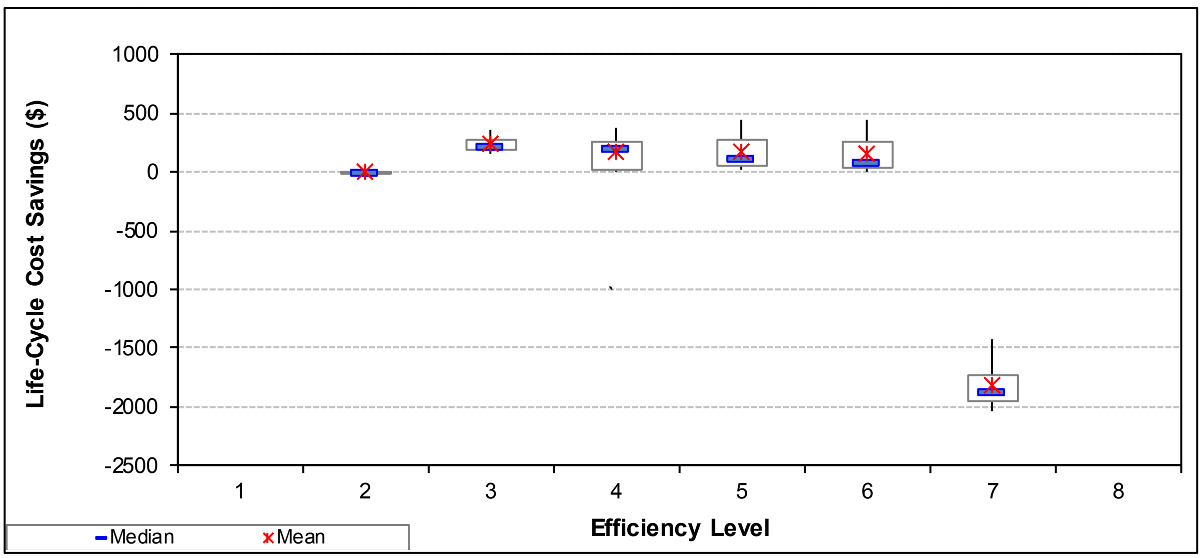

Figure 8B.2.21 LCC Savings Statistical Results for Vertical Closed Solid, Self-Contained, Ice-Cream Temperature (VCS.SC.I)

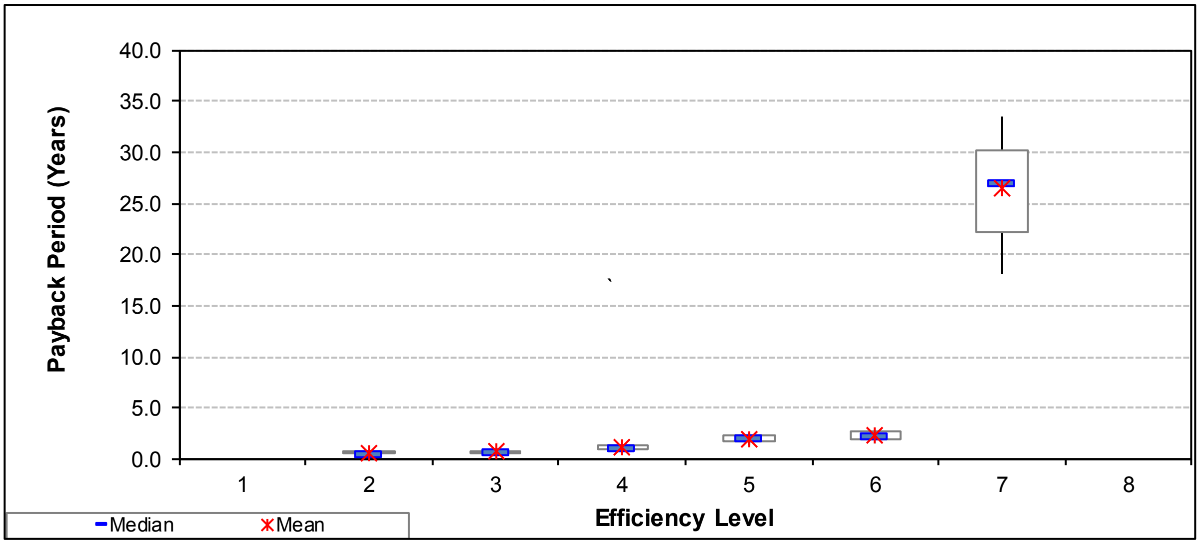

Figure 8B.2.22 PBP Statistical Results for Vertical Closed Solid, Self-Contained, Ice-Cream Temperature (VCS.SC.I)

8B.2.12 Life-Cycle Cost Results for Semi-Vertical Open, Remote Condensing, Medium Temperature (SVO.RC.M)

Table 8B.2.12 LCC Results for Semi-Vertical Open, Remote Condensing, Medium Temperature (SVO.RC.M)

		Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				
						% of Customers that Experience			
Efficiency Level Number	Efficiency Level (kWh/yr)	Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	Net Cost (%)	No Impact (%)	Net Benefit (%)	Payback Period, Median (Years)
1	13,279	8,329	16,907	25,236	NA	NA	NA	NA	NA
2	13,179	8,341	16,821	25,161	74	0	75	25	1.31
3	12,355	8,547	16,098	24,645	552	0	51	49	2.64
4	10,114	9,455	14,347	23,802	1,217	0	29	71	4.34
5	10,065	9,517	14,304	23,821	1,008	13	16	72	4.50
6	9,949	11,511	14,202	25,713	(1,015)	85	3	12	11.60
7	9,949	NA	NA	NA	NA	NA	NA	NA	NA
8	9,949	NA	NA	NA	NA	NA	NA	NA	NA

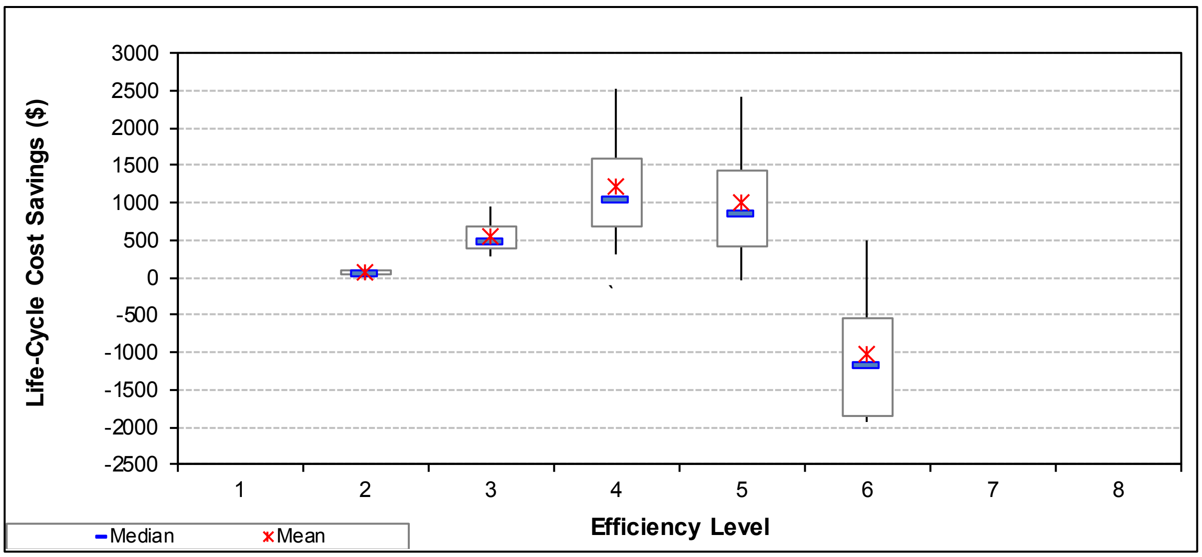

Figure 8B.2.23 LCC Savings Statistical Results for Semi-Vertical Open, Remote Condensing, Medium Temperature (SVO.RC.M)

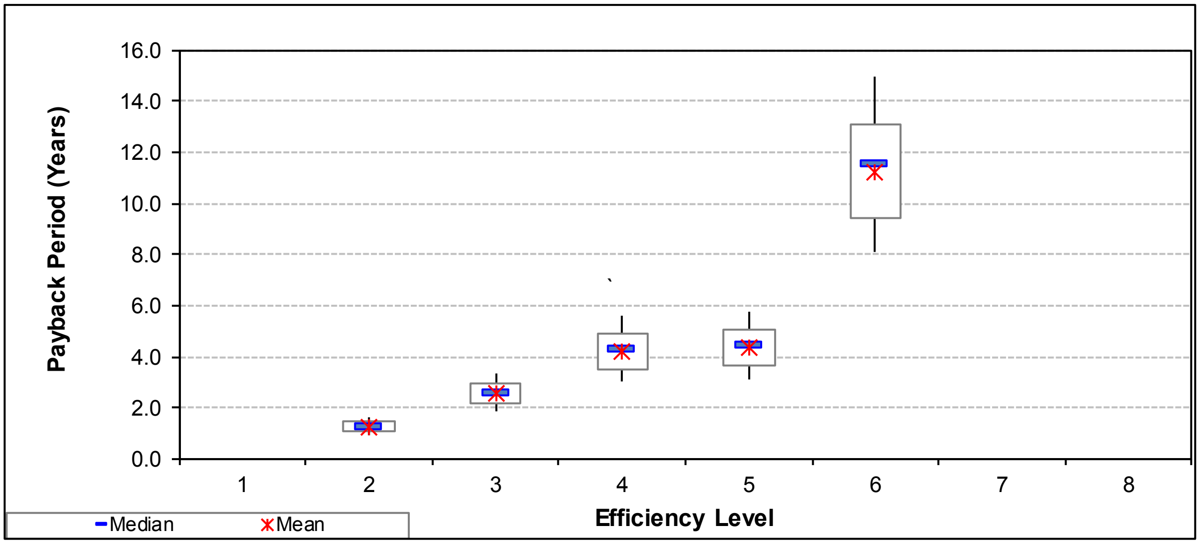

Figure 8B.2.24 PBP Statistical Results for Semi-Vertical Open, Remote Condensing, Medium Temperature (SVO.RC.M)

8B.2.13 Life-Cycle Cost Results for Semi-Vertical Open, Self-Contained, Medium Temperature (SVO.SC.M)

Table 8B.2.13 LCC Results for Semi-Vertical Open, Self-Contained, Medium Temperature (SVO.SC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
						% of Customers that Experience			
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	9,758	3,813	13,153	16,966	NA	NA	NA	NA	NA
2	9,736	3,816	13,128	16,944	22	0	81	19	1.24
3	9,396	3,885	12,744	16,629	324	0	61	39	1.97
4	9,255	3,914	12,600	16,514	335	0	43	57	2.06
5	8,501	4,314	11,866	16,180	588	0	25	75	4.43
6	8,481	4,359	11,843	16,202	492	12	14	75	4.75
7	8,439	5,049	11,796	16,844	(202)	69	4	27	10.36
8	8,439	NA	NA	NA	NA	NA	NA	NA	NA

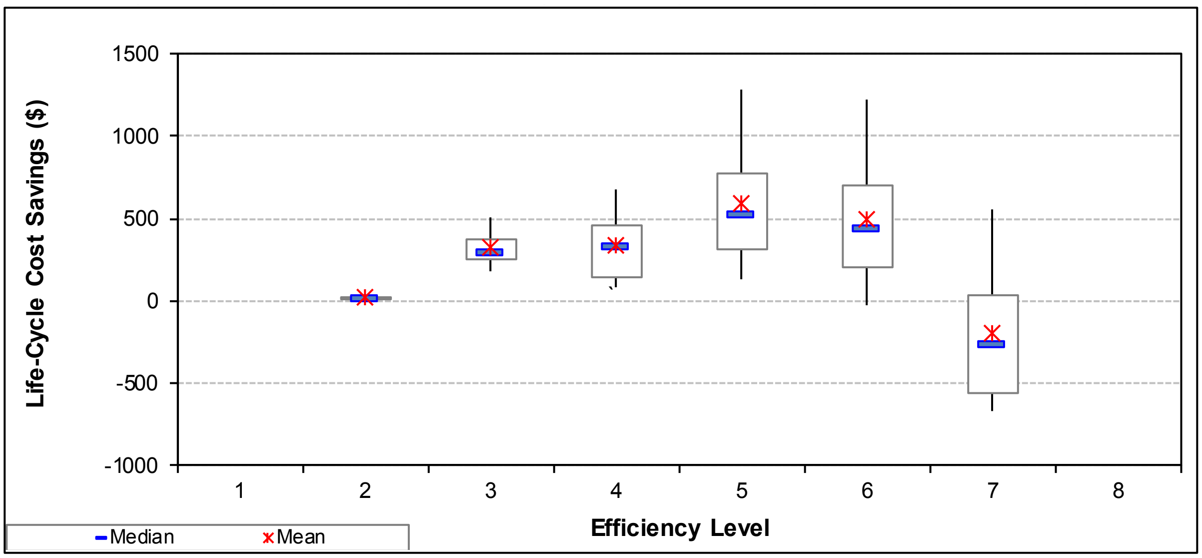

Figure 8B.2.25 LCC Savings Statistical Results for Semi-Vertical Open, Self-Contained, Medium Temperature (SVO.SC.M)

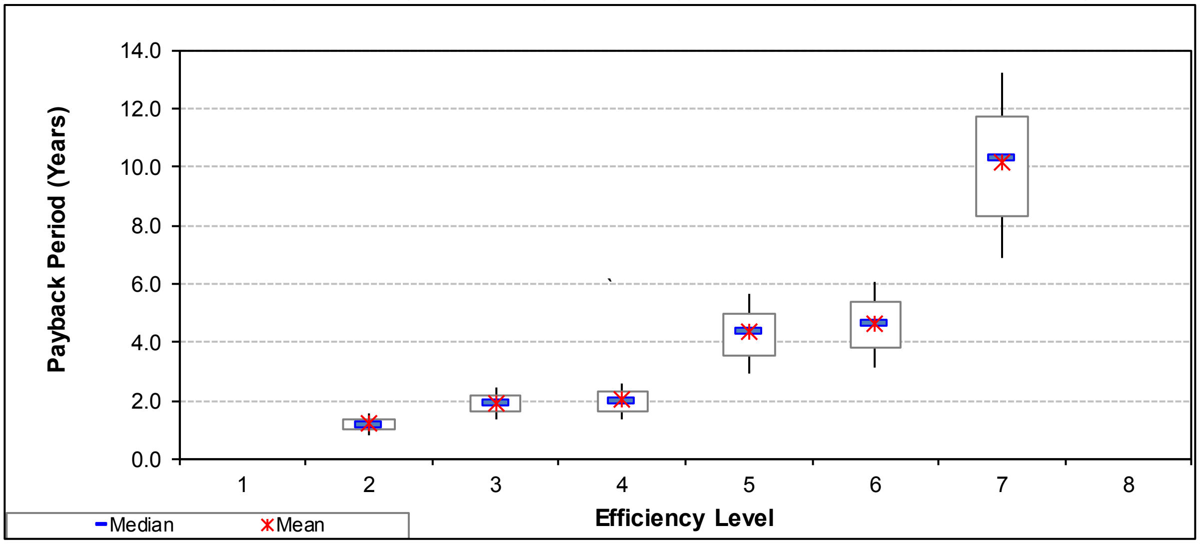

Figure 8B.2.26 PBP Statistical Results for Semi-Vertical Open, Self-Contained, Medium Temperature (SVO.SC.M)

8B.2.14 Life-Cycle Cost Results for Service Over Counter, Remote Condensing, Medium Temperature (SOC.RC.M)

Table 8B.2.14 LCC Results for Service Over Counter, Remote Condensing, Medium Temperature (SOC.RC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
						% of Customers that Experience			
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	9,534	12,748	15,245	27,993	NA	NA	NA	NA	NA
2	9,353	12,766	15,106	27,872	118	0	82	18	1.25
3	9,115	12,799	14,906	27,704	226	0	64	36	1.44
4	7,455	13,343	13,511	26,854	998	0	47	53	3.31
5	7,413	13,398	13,475	26,873	766	14	32	54	3.55
6	7,356	13,570	13,443	27,012	495	29	18	53	4.41
7	7,274	15,050	13,372	28,423	(982)	89	5	6	11.88
8	7,274	NA	NA	NA	NA	NA	NA	NA	NA

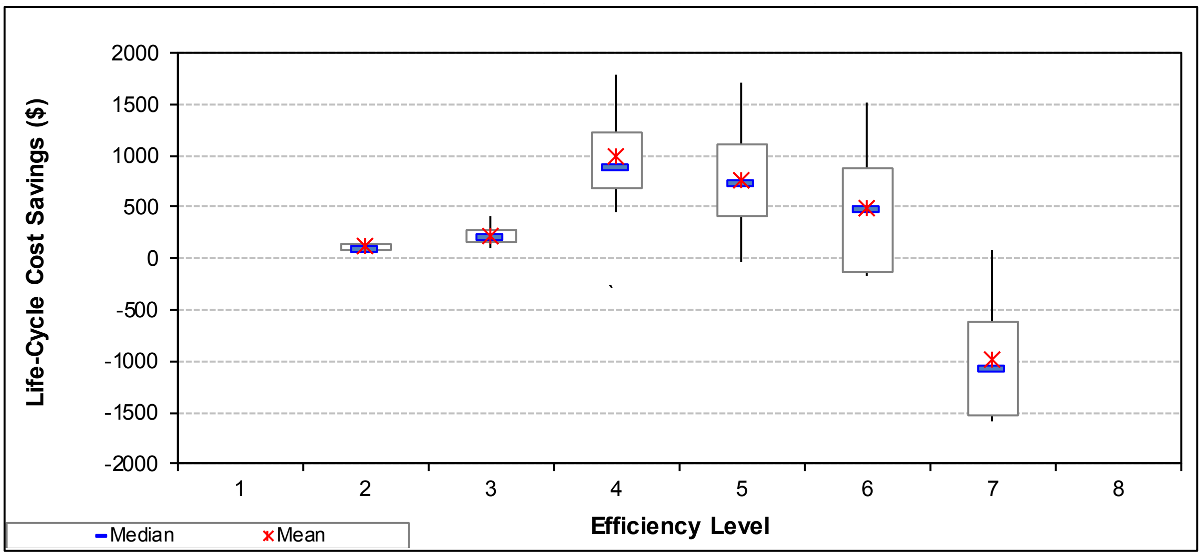

Figure 8B.2.27 LCC Savings Statistical Results for Service Over Counter, Remote Condensing, Medium Temperature (SOC.RC.M)

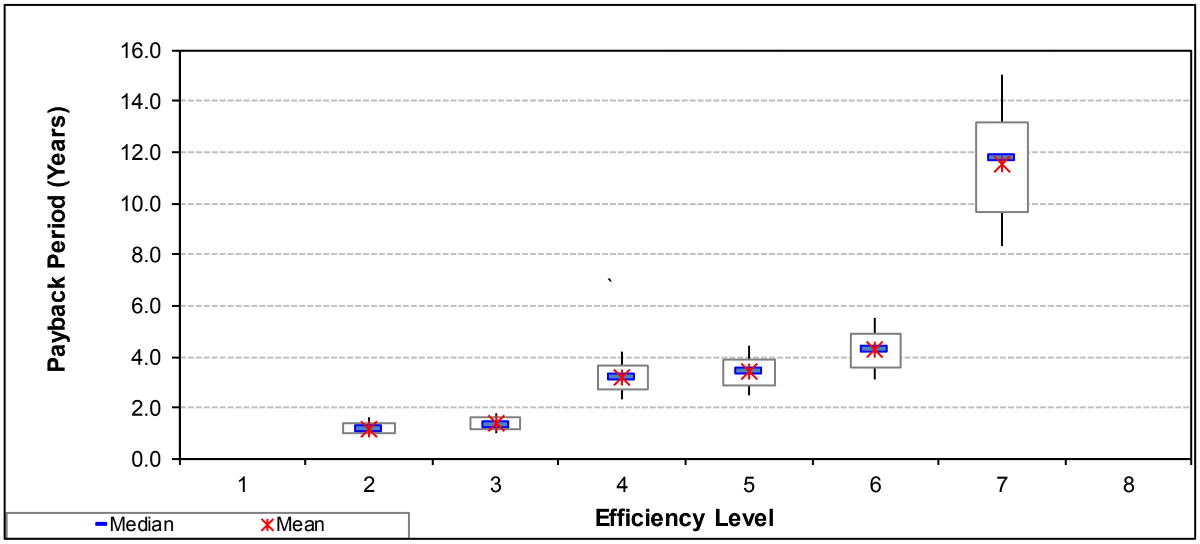

Figure 8B.2.28 PBP Statistical Results for Service Over Counter, Remote Condensing, Medium Temperature (SOC.RC.M)

8B.2.15 Life-Cycle Cost Results for Service Over Counter, Self-Contained, Medium Temperature (SOC.SC.M)

Table 8B.2.15 LCC Results for Service Over Counter, Self-Contained, Medium Temperature (SOC.SC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
		Installed Cost (2012$)	Discounted Operating Cost	All Customers (2012$)	Customers' Average Savings	% of Customers that Experience			
						Cost (%)	No Impact (%)	Benefit (%)	
1	11,534	12,161	15,575	27,736	NA	NA	NA	NA	NA
2	10,235	12,266	14,666	26,932	795	0	85	15	1.03
3	9,869	12,314	14,364	26,678	646	0	70	30	1.12
4	9,783	12,339	14,301	26,640	466	0	55	45	1.24
5	8,039	12,883	12,863	25,747	1,242	0	40	60	2.35
6	7,986	12,939	12,819	25,757	1,016	11	28	62	2.49
7	7,920	13,110	12,777	25,887	740	25	16	60	2.99
8	7,814	14,591	12,687	27,277	(735)	80	5	16	7.42

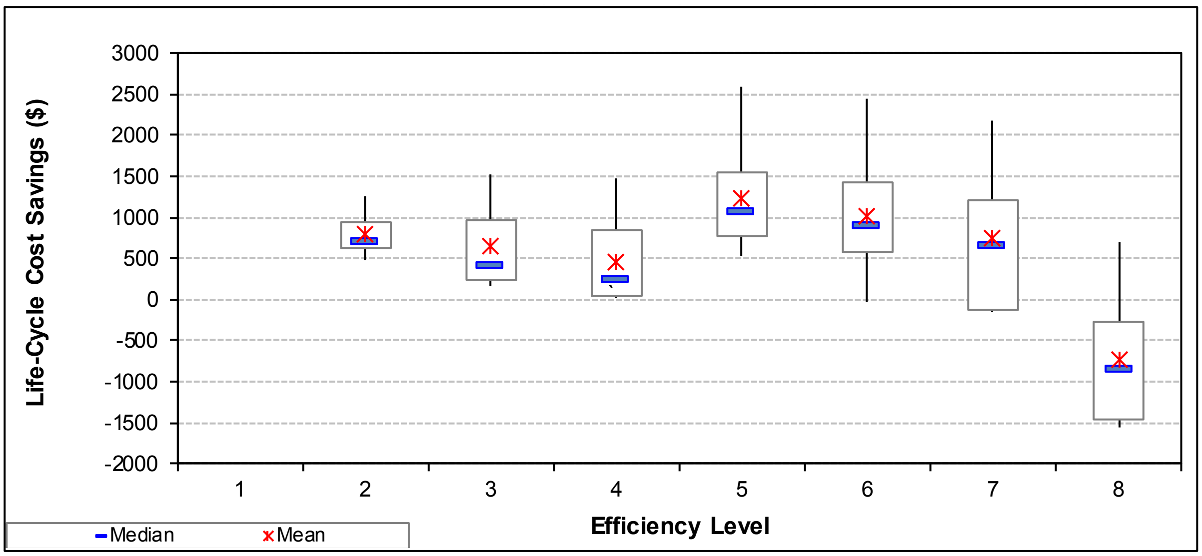

Figure 8B.2.29 LCC Savings Statistical Results for Service Over Counter, Self-Contained, Medium Temperature (SOC.SC.M)

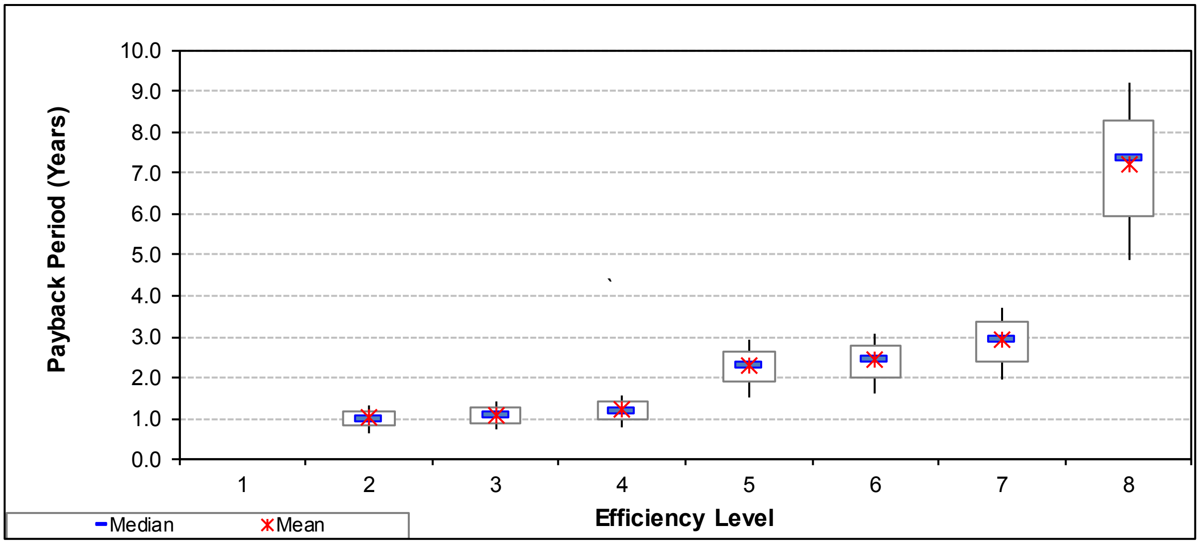

Figure 8B.2.30 PBP Statistical Results for Service Over Counter, Self-Contained, Medium Temperature (SOC.SC.M)

8B.2.16 Life-Cycle Cost Results for Horizontal Open, Remote Condensing, Medium Temperature (HZO.RC.M)

Table 8B.2.16 LCC Results for Horizontal Open, Remote Condensing, Medium Temperature (HZO.RC.M)

		Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				
						% of Customers that Experience			
Efficiency Level Number	Efficiency Level (kWh/yr)	Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	Net Cost (%)	No Impact (%)	Net Benefit (%)	Payback Period, Median (Years)
1	5,267	8,056	8,916	16,972	NA	NA	NA	NA	NA
2	5,173	9,406	8,837	18,243	(1,271)	78	22	0	161.23
3	5,173	NA	NA	NA	NA	NA	NA	NA	NA
4	5,173	NA	NA	NA	NA	NA	NA	NA	NA
5	5,173	NA	NA	NA	NA	NA	NA	NA	NA
6	5,173	NA	NA	NA	NA	NA	NA	NA	NA
7	5,173	NA	NA	NA	NA	NA	NA	NA	NA
8	5,173	NA	NA	NA	NA	NA	NA	NA	NA

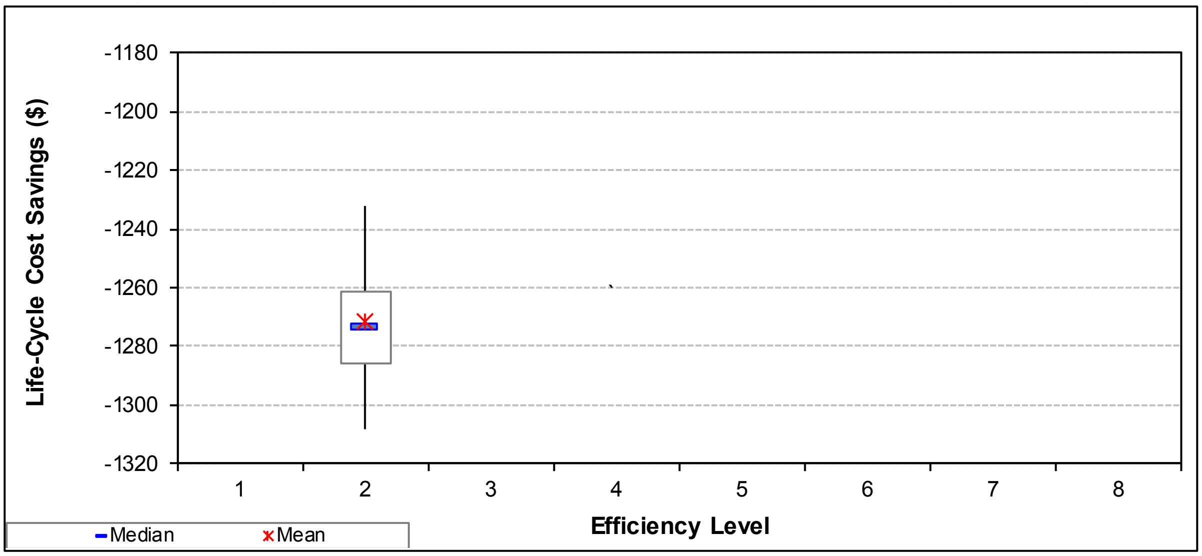

Figure 8B.2.31 LCC Savings Statistical Results for Horizontal Open, Remote Condensing, Medium Temperature (HZO.RC.M)

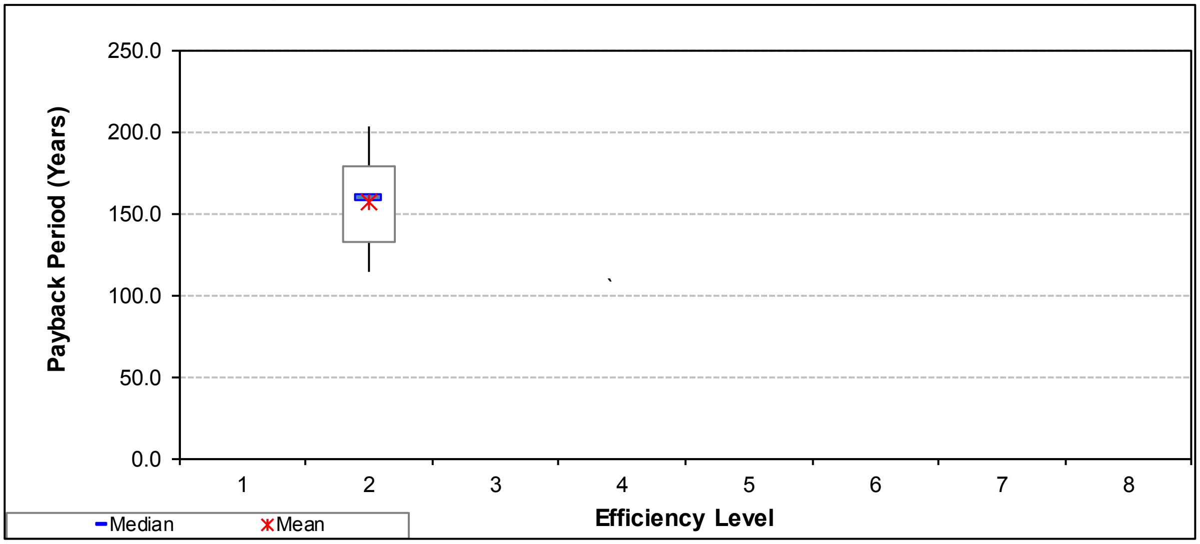

Figure 8B.2.32 PBP Statistical Results for Horizontal Open, Remote Condensing, Medium Temperature (HZO.RC.M)

8B.2.17 Life-Cycle Cost Results for Horizontal Open, Remote Condensing, Low Temperature (HZO.RC.L)

Table 8B.2.17 LCC Results for Horizontal Open, Remote Condensing, Low Temperature (HZO.RC.L)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
						% of Customers that Experience			
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	12,082	8,895	14,989	23,884	NA	NA	NA	NA	NA
2	11,759	11,301	14,718	26,019	(2,135)	86	14	0	83.78
3	11,759	NA	NA	NA	NA	NA	NA	NA	NA
4	11,759	NA	NA	NA	NA	NA	NA	NA	NA
5	11,759	NA	NA	NA	NA	NA	NA	NA	NA
6	11,759	NA	NA	NA	NA	NA	NA	NA	NA
7	11,759	NA	NA	NA	NA	NA	NA	NA	NA
8	11,759	NA	NA	NA	NA	NA	NA	NA	NA

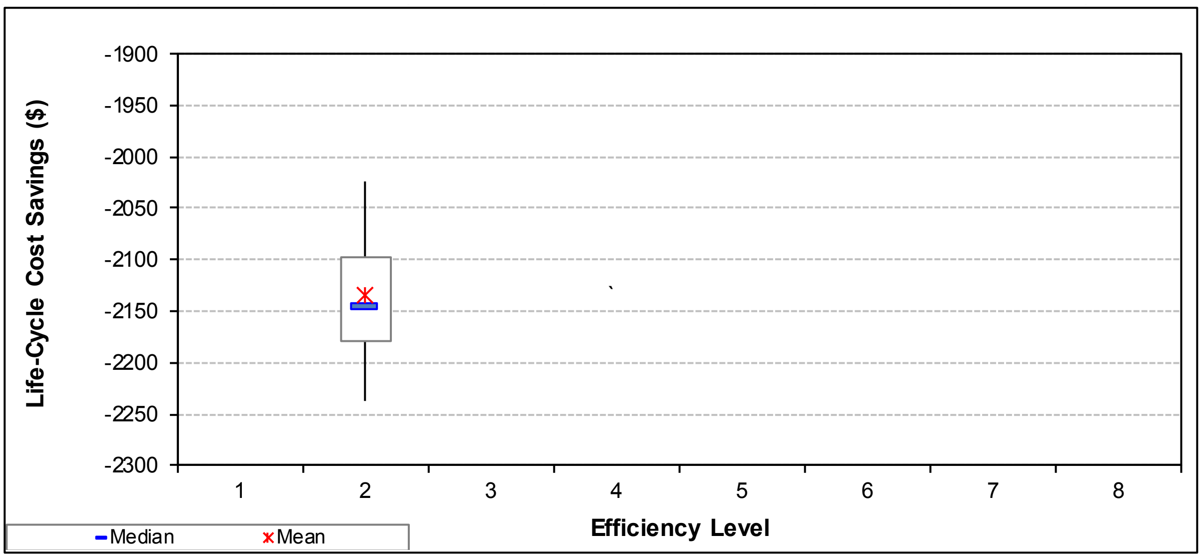

Figure 8B.2.33 LCC Savings Statistical Results for Horizontal Open, Remote Condensing, Low Temperature (HZO.RC.L)

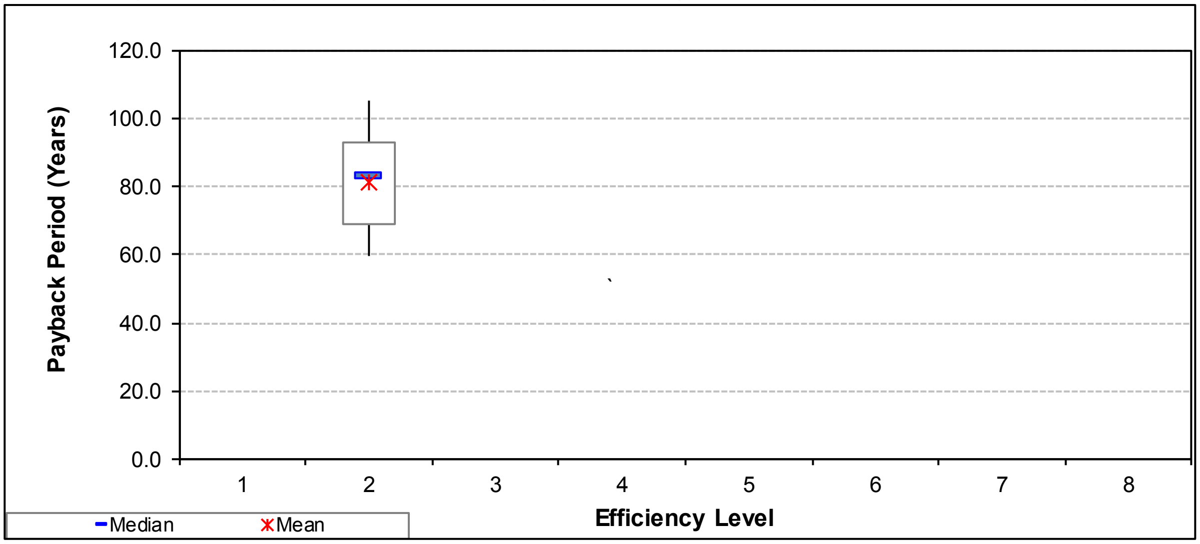

Figure 8B.2.34 PBP Statistical Results for Horizontal Open, Remote Condensing, Low Temperature (HZO.RC.L)

8B.2.18 Life-Cycle Cost Results for Horizontal Open, Self-Contained, Medium Temperature (HZO.SC.M)

Table 8B.2.18 LCC Results for Horizontal Open, Self-Contained, Medium Temperature (HZO.SC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	% of Customers that Experience: Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	5,398	2,342	7,066	9,408	NA	NA	NA	NA	NA
2	5,388	2,343	7,055	9,399	9	0	75	25	1.89
3	5,330	2,356	6,999	9,354	49	0	49	51	2.42
4	5,289	2,405	6,954	9,358	29	19	24	57	6.40
5	5,206	3,340	6,862	10,202	(822)	98	2	0	55.78
6	5,206	NA	NA	NA	NA	NA	NA	NA	NA
7	5,206	NA	NA	NA	NA	NA	NA	NA	NA
8	5,206	NA	NA	NA	NA	NA	NA	NA	NA

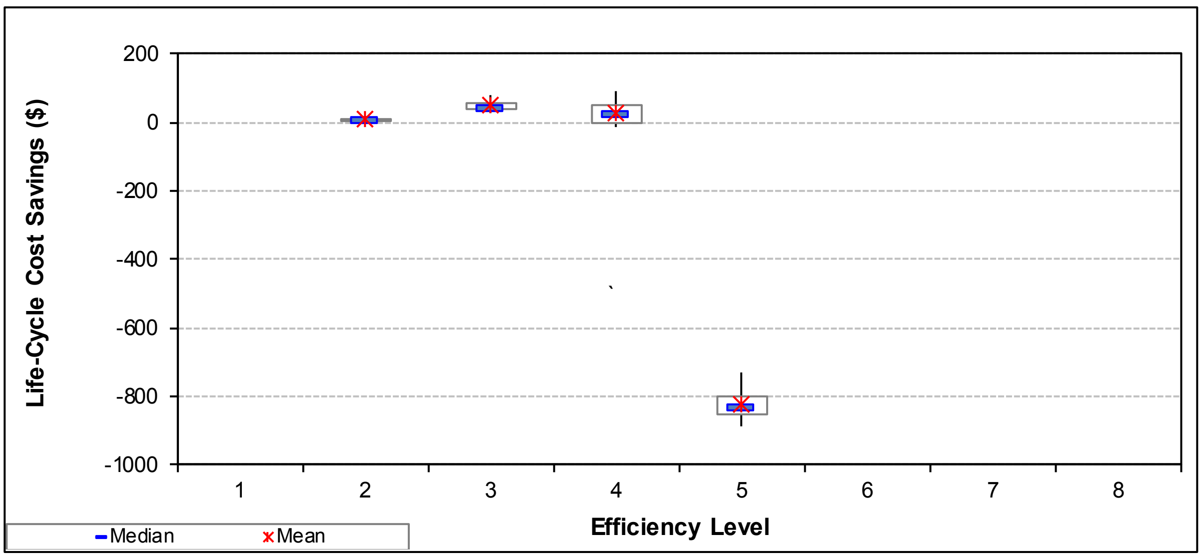

Figure 8B.2.35 LCC Savings Statistical Results for Horizontal Open, Self-Contained, Medium Temperature (HZO.SC.M)

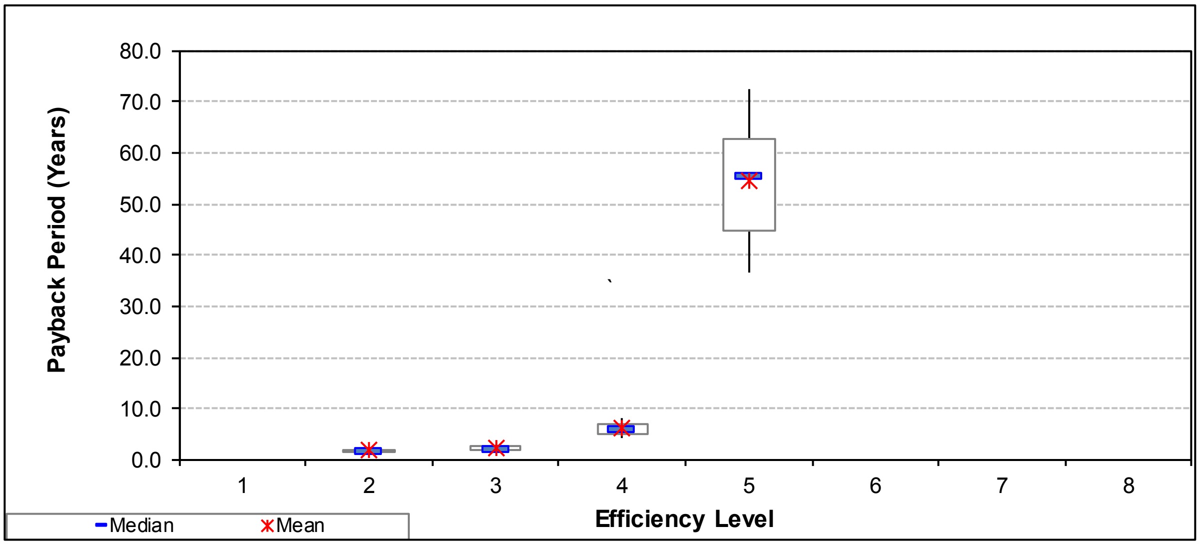

Figure 8B.2.36 PBP Statistical Results for Horizontal Open, Self-Contained, Medium Temperature (HZO.SC.M)

8B.2.19 Life-Cycle Cost Results for Horizontal Open, Self-Contained, Low Temperature (HZO.SC.L)

Table 8B.2.19 LCC Results for Horizontal Open, Self-Contained, Low Temperature (HZO.SC.L)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	% of Customers that Experience: Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	10,994	3,691	13,891	17,582	NA	NA	NA	NA	NA
2	10,916	4,251	13,804	18,056	(474)	72	28	0	73.62
3	10,916	NA	NA	NA	NA	NA	NA	NA	NA
4	10,916	NA	NA	NA	NA	NA	NA	NA	NA
5	10,916	NA	NA	NA	NA	NA	NA	NA	NA
6	10,916	NA	NA	NA	NA	NA	NA	NA	NA
7	10,916	NA	NA	NA	NA	NA	NA	NA	NA
8	10,916	NA	NA	NA	NA	NA	NA	NA	NA

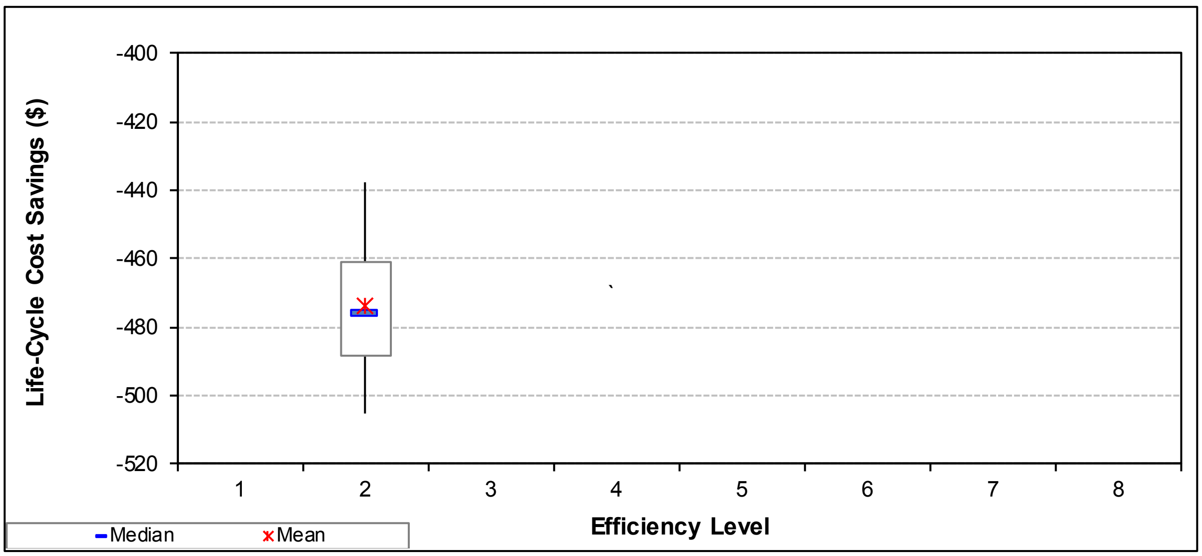

Figure 8B.2.37 LCC Savings Statistical Results for Horizontal Open, Self-Contained, Low Temperature (HZO.SC.L)

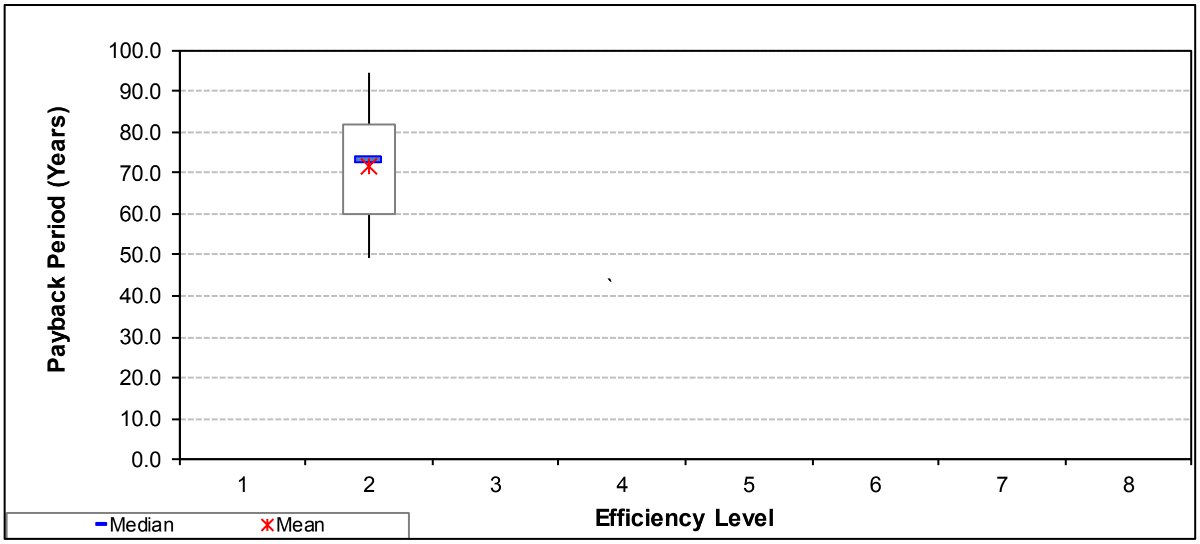

Figure 8B.2.38 PBP Statistical Results for Horizontal Open, Self-Contained, Low Temperature (HZO.SC.L)

8B.2.20 Life-Cycle Cost Results for Horizontal Closed Transparent, Self-Contained, Medium Temperature (HCT.SC.M)

Table 8B.2.20 LCC Results for Horizontal Closed Transparent, Self-Contained, Medium Temperature (HCT.SC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers: Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Life-Cycle Cost Savings: Affected Customers' Average Savings (2012$)	% of Customers that Experience: Net Cost (%)	No Impact (%)	Net Benefit (%)	Payback Period, Median (Years)
1	831	2,047	1,854	3,900	NA	NA	NA	NA	NA
2	741	2,051	1,749	3,800	99	0	85	15	0.48
3	683	2,057	1,685	3,742	107	0	70	30	0.69
4	632	2,064	1,631	3,695	118	0	54	46	0.88
5	305	2,161	1,263	3,423	359	0	38	62	2.24
6	275	2,175	1,236	3,411	307	0	25	75	2.42
7	244	2,220	1,200	3,420	254	18	12	70	3.08
8	181	2,812	1,127	3,939	(294)	89	1	10	12.26

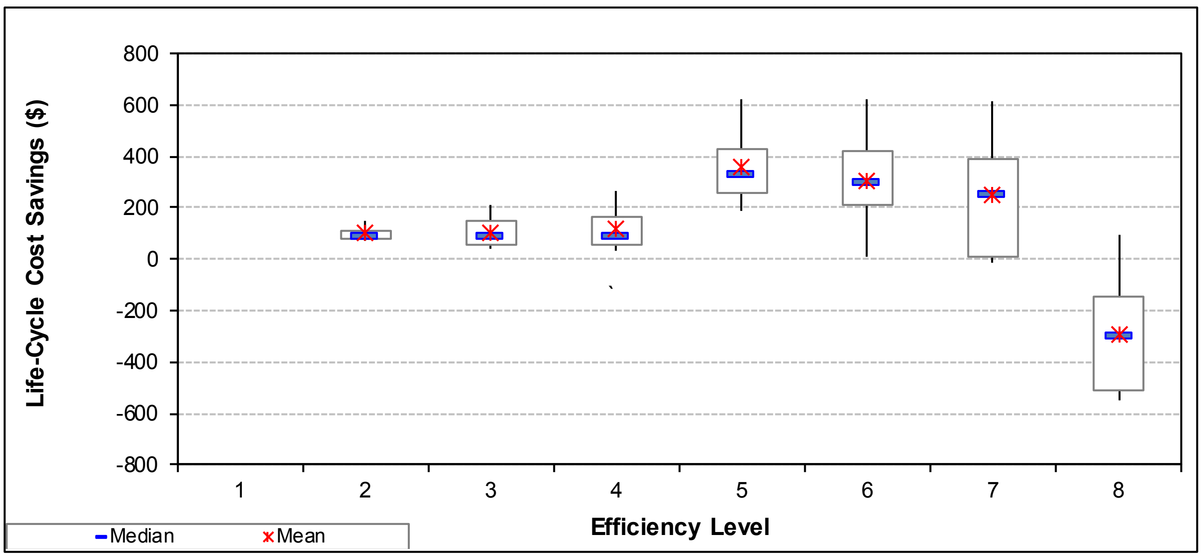

Figure 8B.2.39 LCC Savings Statistical Results for Horizontal Closed Transparent, Self-Contained, Medium Temperature (HCT.SC.M)

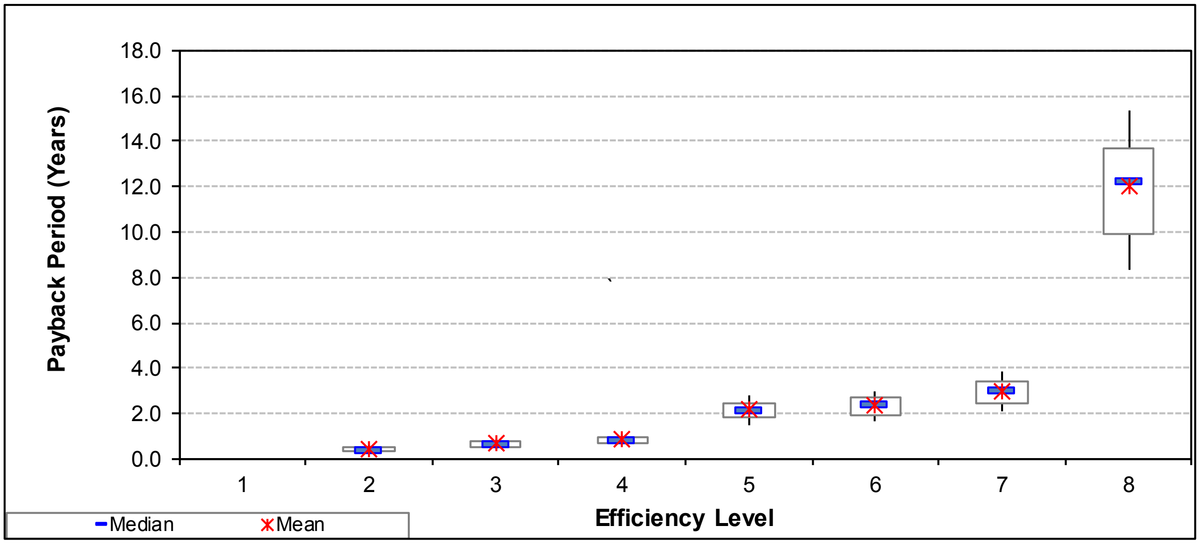

Figure 8B.2.40 PBP Statistical Results for Horizontal Closed Transparent, Self-Contained, Medium Temperature (HCT.SC.M)

8B.2.21 Life-Cycle Cost Results for Horizontal Closed Transparent, Self-Contained, Low Temperature (HCT.SC.L)

Table 8B.2.21 LCC Results for Horizontal Closed Transparent, Self-Contained, Low Temperature (HCT.SC.L)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers: Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Life-Cycle Cost Savings: Affected Customers' Average Savings (2012$)	% of Customers that Experience: Net Cost (%)	No Impact (%)	Net Benefit (%)	Payback Period, Median (Years)
1	1,887	2,221	2,683	4,904	NA	NA	NA	NA	NA
2	1,649	2,229	2,467	4,696	205	0	88	12	0.34
3	1,499	2,240	2,336	4,576	217	0	75	26	0.53
4	667	2,337	1,589	3,926	791	0	61	39	1.00
5	647	2,344	1,574	3,918	571	0	45	55	1.05
6	622	2,358	1,558	3,917	446	11	29	60	1.15
7	572	2,403	1,513	3,916	369	23	14	63	1.47
8	432	3,204	1,385	4,590	(355)	76	1	23	7.15

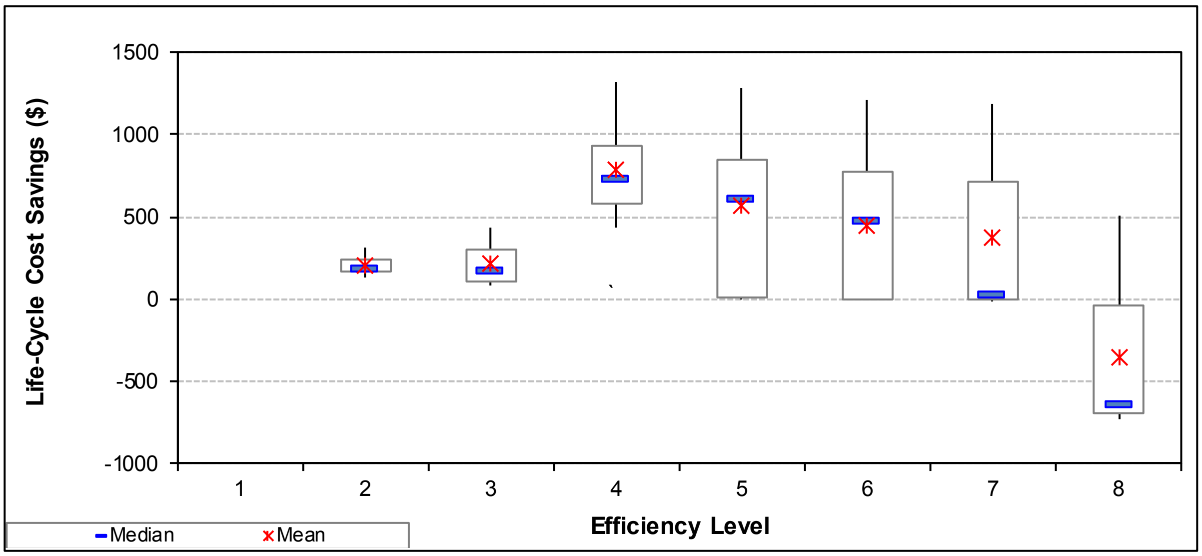

Figure 8B.2.41 LCC Savings Statistical Results for Horizontal Closed Transparent, Self-Contained, Low Temperature (HCT.SC.L)

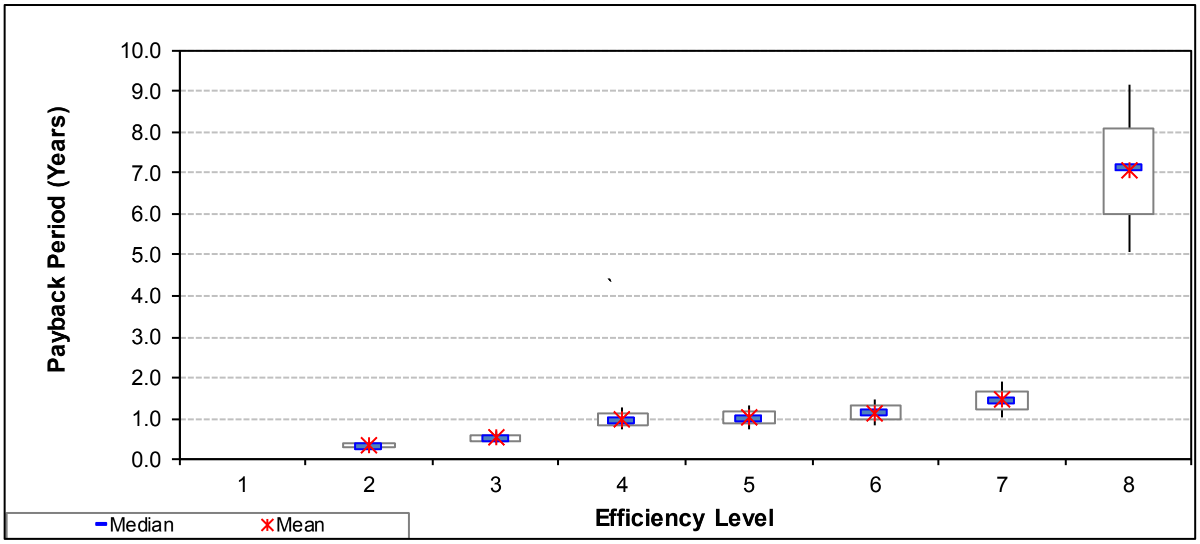

Figure 8B.2.42 PBP Statistical Results for Horizontal Closed Transparent, Self-Contained, Low Temperature (HCT.SC.L)

8B.2.22 Life-Cycle Cost Results for Horizontal Closed Transparent, Self-Contained, Ice-Cream Temperature (HCT.SC.I)

Table 8B.2.22 LCC Results for Horizontal Closed Transparent, Self-Contained, Ice-Cream Temperature (HCT.SC.I)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	% of Customers that Experience			
						Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	1,203	2,329	2,016	4,344	NA	NA	NA	NA	NA
2	1,174	2,331	1,991	4,322	22	0	74	26	0.88
3	1,121	2,346	1,953	4,299	35	0	49	51	2.39
4	1,045	2,391	1,889	4,279	42	2	23	75	4.28
5	776	3,461	1,663	5,124	(811)	99	1	0	27.99
6	776	NA	NA	NA	NA	NA	NA	NA	NA
7	776	NA	NA	NA	NA	NA	NA	NA	NA
8	776	NA	NA	NA	NA	NA	NA	NA	NA

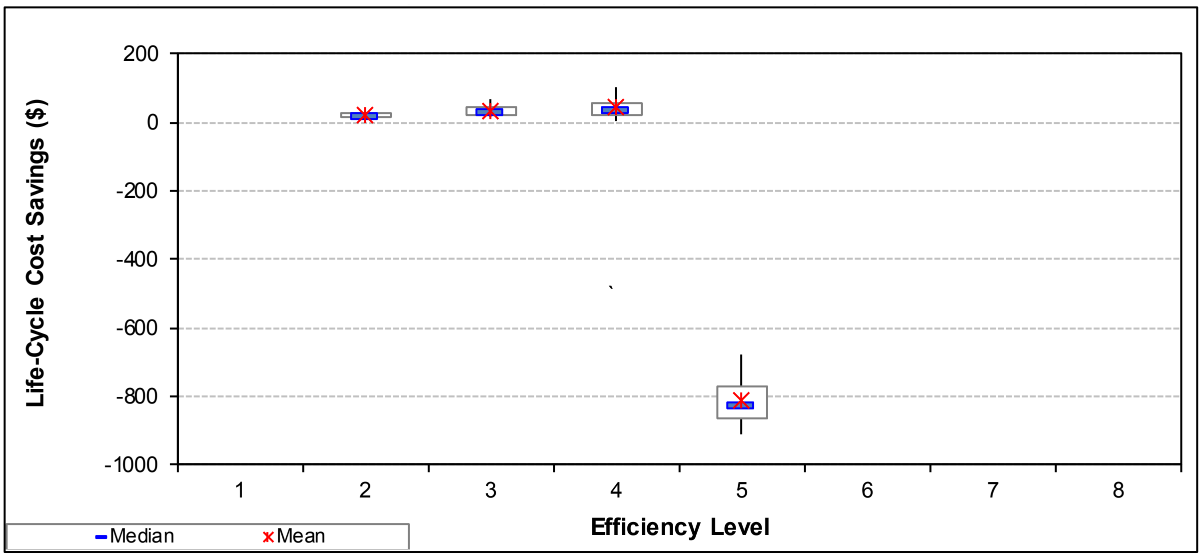

Figure 8B.2.43 LCC Savings Statistical Results for Horizontal Closed Transparent, Self-Contained, Ice-Cream Temperature (HCT.SC.I)

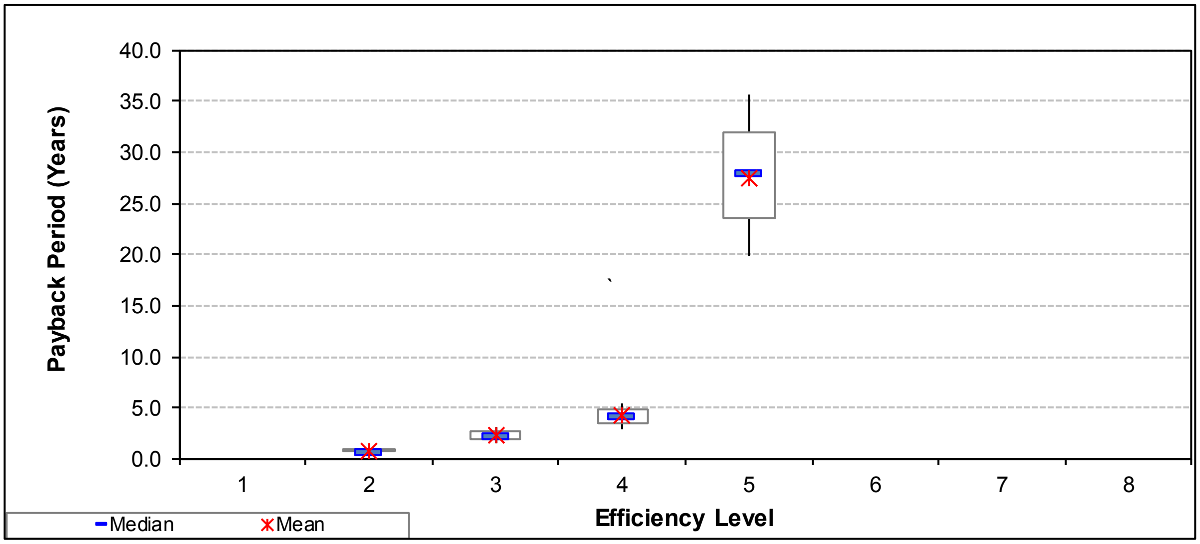

Figure 8B.2.44 PBP Statistical Results for Horizontal Closed Transparent, Self-Contained, Ice-Cream Temperature (HCT.SC.I)

8B.2.23 Life-Cycle Cost Results for Horizontal Closed Solid, Self-Contained, Medium Temperature (HCS.SC.M)

Table 8B.2.23 LCC Results for Horizontal Closed Solid, Self-Contained, Medium Temperature (HCS.SC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers: Installed Cost (2012$)	Life-Cycle Cost, All Customers: Total Discounted Operating Cost (2012$)	Life-Cycle Cost, All Customers: LCC, All Customers (2012$)	Life-Cycle Cost Savings: Affected Customers' Average Savings (2012$)	% of Customers that Experience: Net Cost (%)	% of Customers that Experience: No Impact (%)	% of Customers that Experience: Net Benefit (%)	Payback Period, Median (Years)
1	267	1,950	997	2,947	NA	NA	NA	NA	NA
2	238	1,951	972	2,924	23	0	83	17	0.50
3	220	1,957	959	2,916	19	0	65	35	1.64
4	203	1,964	948	2,912	17	1	48	51	2.54
5	183	1,979	937	2,916	9	29	31	40	4.28
6	153	2,022	911	2,933	(10)	66	15	19	7.43
7	90	2,490	857	3,347	(423)	98	2	0	34.05
8	90	NA	NA	NA	NA	NA	NA	NA	NA

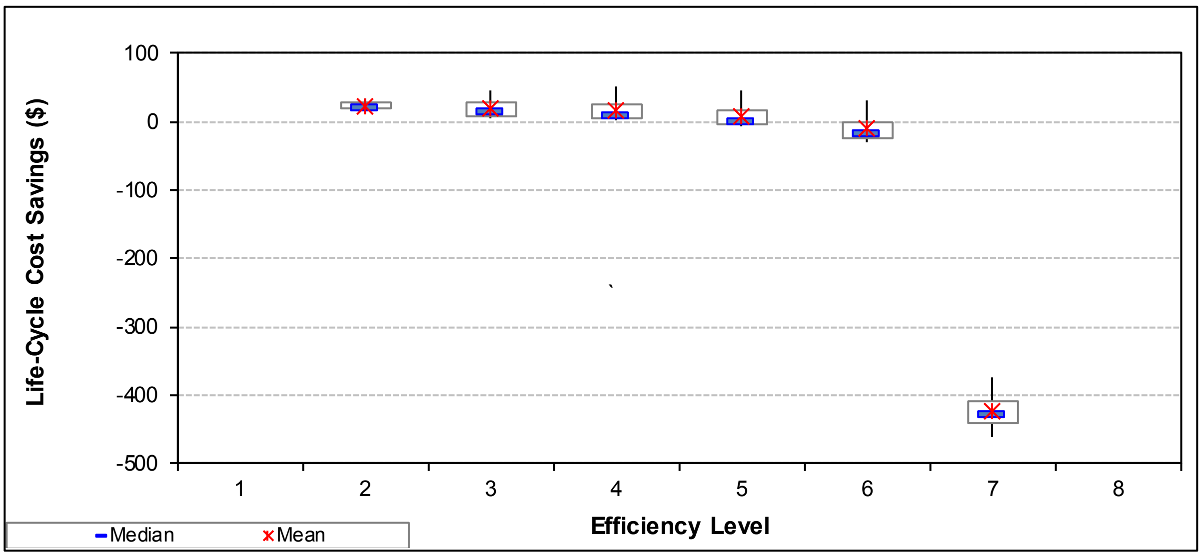

Figure 8B.2.45 LCC Savings Statistical Results for Horizontal Closed Solid, Self-Contained, Medium Temperature (HCS.SC.M)

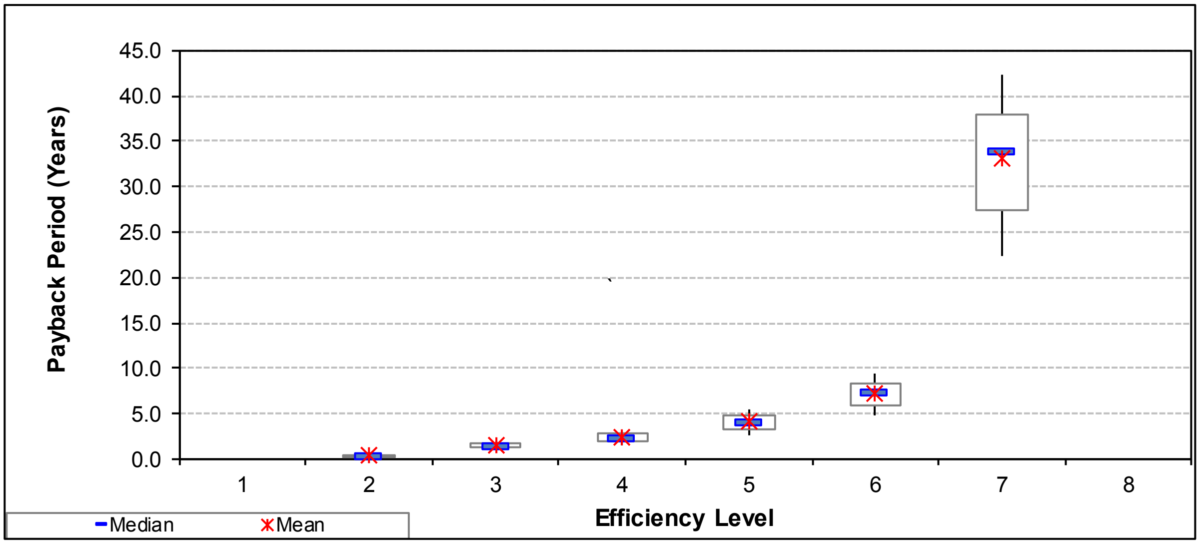

Figure 8B.2.46 PBP Statistical Results for Horizontal Closed Solid, Self-Contained, Medium Temperature (HCS.SC.M)

8B.2.24 Life-Cycle Cost Results for Horizontal Closed Solid, Self-Contained, Low Temperature (HCS.SC.L)

Table 8B.2.24 LCC Results for Horizontal Closed Solid, Self-Contained, Low Temperature (HCS.SC.L)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	% of Customers that Experience			
						Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	770	1,973	1,433	3,406	NA	NA	NA	NA	NA
2	686	1,976	1,362	3,338	68	0	84	16	0.26
3	632	1,981	1,318	3,299	72	0	67	33	0.58
4	588	1,988	1,284	3,272	75	0	50	50	0.86
5	534	2,003	1,244	3,246	81	0	33	67	1.36
6	464	2,046	1,184	3,231	81	2	16	82	2.57
7	271	2,681	1,020	3,700	(401)	98	2	0	14.98
8	271	NA	NA	NA	NA	NA	NA	NA	NA

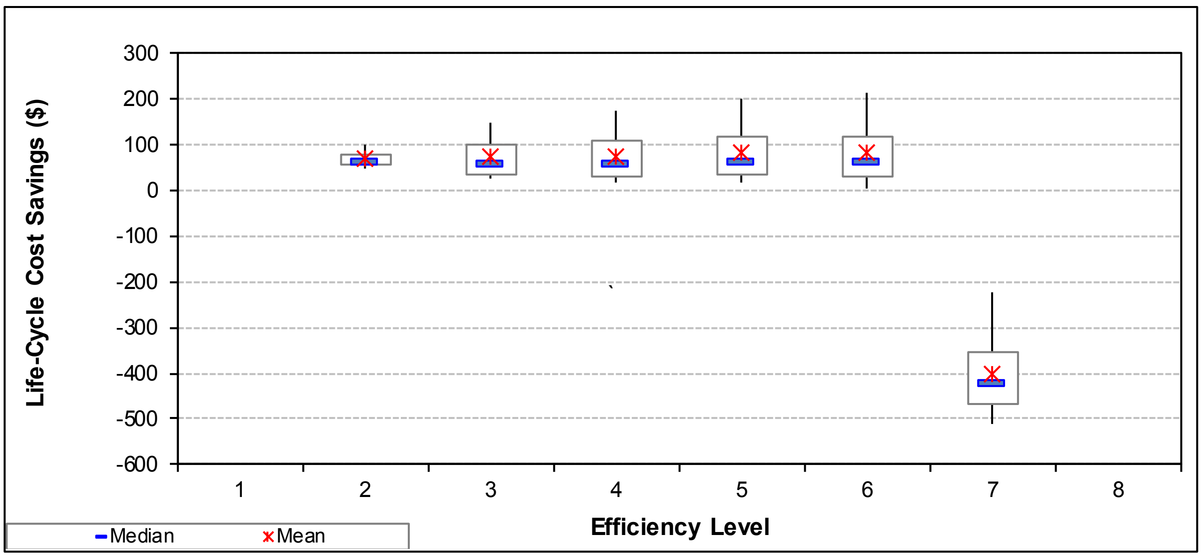

Figure 8B.2.47 LCC Savings Statistical Results for Horizontal Closed Solid, Self-Contained, Low Temperature (HCS.SC.L)

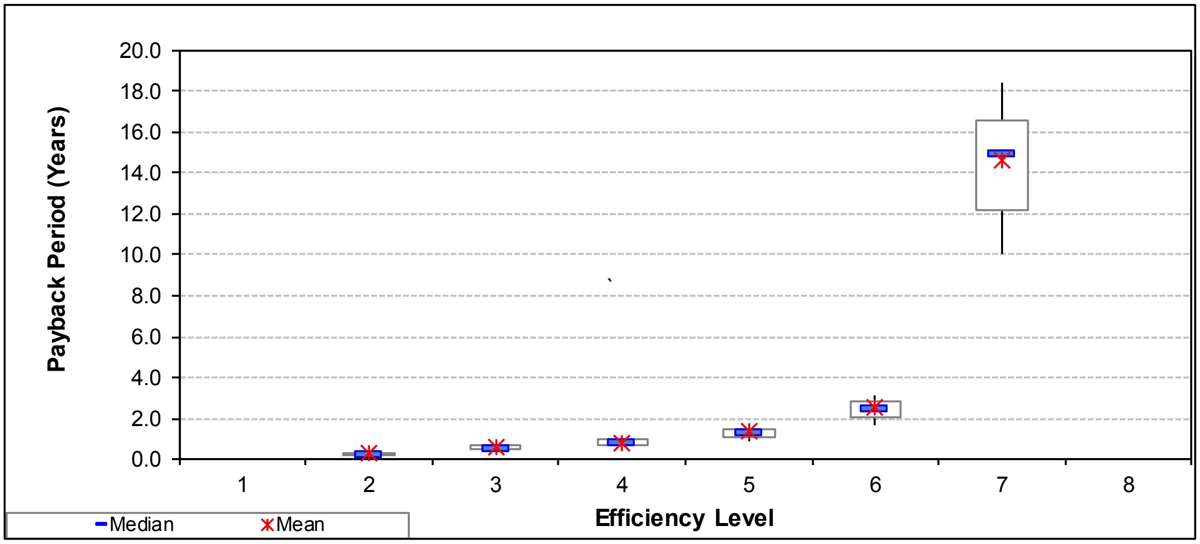

Figure 8B.2.48 PBP Statistical Results for Horizontal Closed Solid, Self-Contained, Low Temperature (HCS.SC.L)

8B.2.25 Life-Cycle Cost Results for Pull-Down, Self-Contained, Medium Temperature (PD.SC.M)

Table 8B.2.25 LCC Results for Pull-Down, Self-Contained, Medium Temperature (PD.SC.M)

Efficiency Level Number	Efficiency Level (kWh/yr)	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Payback Period, Median (Years)
		Installed Cost (2012$)	Total Discounted Operating Cost (2012$)	LCC, All Customers (2012$)	Affected Customers' Average Savings (2012$)	% of Customers that Experience			
						Net Cost (%)	No Impact (%)	Net Benefit (%)	
1	2,523	2,949	3,998	6,946	NA	NA	NA	NA	NA
2	1,423	3,002	2,926	5,927	1,010	0	86	14	0.53
3	815	3,121	2,322	5,444	934	0	69	31	1.10
4	804	3,129	2,315	5,444	616	10	53	37	1.15
5	790	3,142	2,307	5,449	457	27	37	36	1.22
6	641	3,292	2,156	5,448	369	27	22	51	1.99
7	597	3,348	2,112	5,460	310	41	11	48	2.27
8	517	4,347	2,031	6,379	(638)	86	1	13	7.61

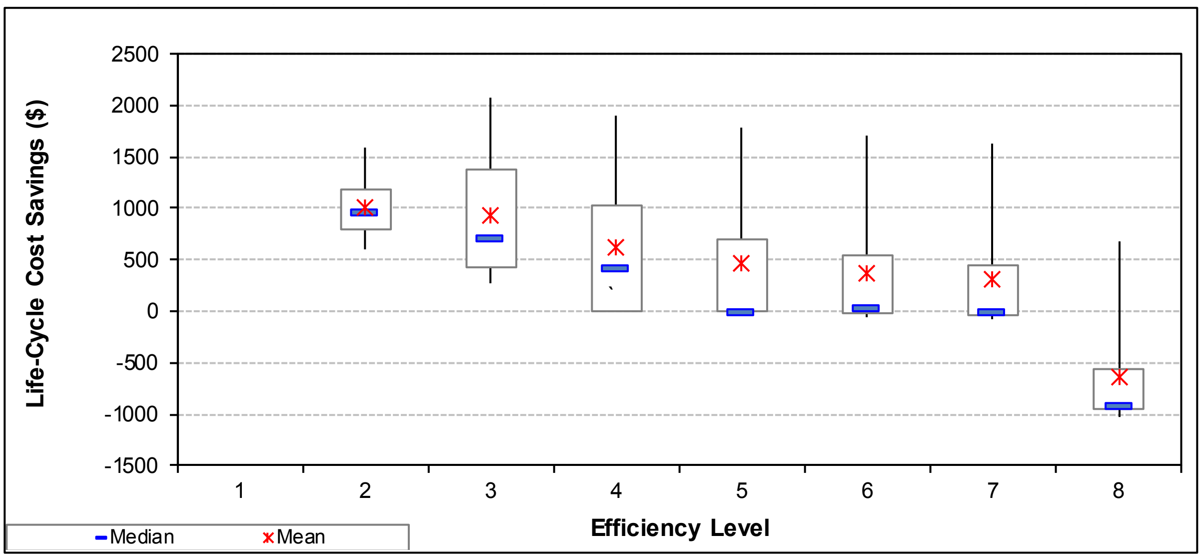

Figure 8B.2.49 LCC Savings Statistical Results for Pull-Down, Self-Contained, Medium Temperature (PD.SC.M)

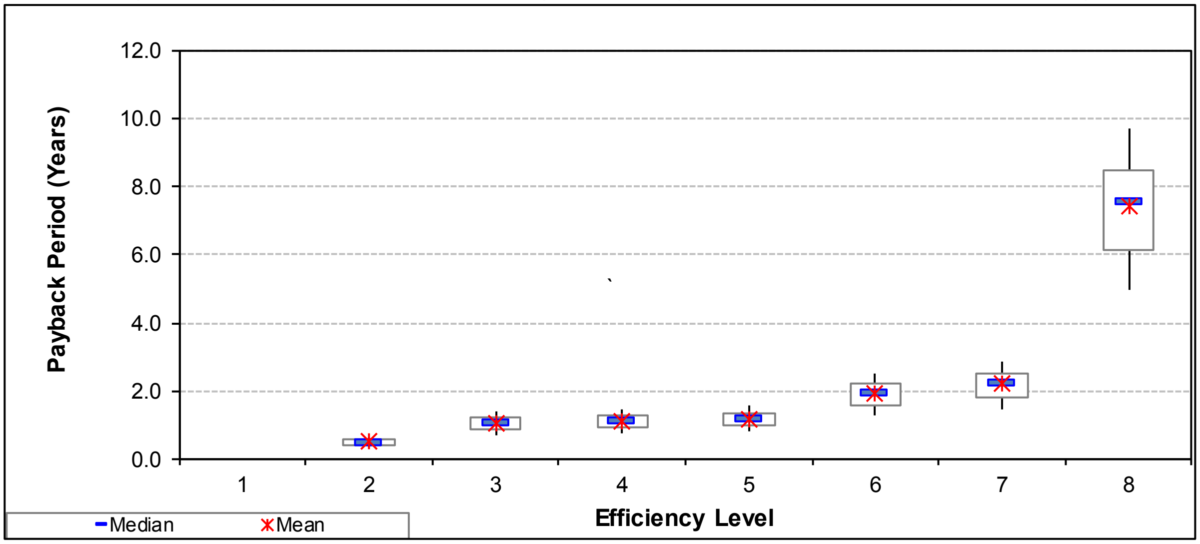

Figure 8B.2.50 PBP Statistical Results for Pull-Down, Self-Contained, Medium Temperature (PD.SC.M)

APPENDIX 8C. UNCERTAINTY AND VARIABILITY IN LIFE-CYCLE COST ANALYSIS

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APPENDIX 8C. UNCERTAINTY AND VARIABILITY IN LCC ANALYSIS

8C.1 INTRODUCTION

The U.S. Department of Energy's (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 examines the variability of the LCC of higher efficiency equipment by varying a wide range of input assumptions. To perform the calculation, analysts 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, in most cases, the model and/or the numerical values for each quantity in the model are not completely known (*i.e.,* there is uncertainty), 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 for establishing standards for commercial refrigeration equipment.

8C.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 lifetime of a refrigerator used in a restaurant is not available at the time of purchase, but rather estimated based upon available historic information. When estimating numerical values expected for quantities at some future date, the exact outcome is rarely known in advance.

8C.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 another parameter. For example, the electricity price rate faced by a customer is dependent on the state where the customer's business is located and the type of business.

8C.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 provides some indication of the extent to which the result depends on the assumptions. 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 price 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 price 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 (*i.e.,* 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.

8C.5 PROBABILITY ANALYSIS AND THE USE OF CRYSTAL BALL®

To quantify the uncertainty and variability that exist in inputs to the engineering, LCC, and payback period analyses, DOE used Microsoft Excel spreadsheets combined with Crystal Ball, a commercially available add-in, to conduct probability analyses. The probability analysis is carried out in the form of Monte Carlo simulations. Simulation refers to any analytical method meant to imitate a real-life system, especially when other analyses are mathematically complex or difficult to reproduce. Without the aid of simulation, a spreadsheet model will only reveal a single outcome, generally the most likely or average scenario.

Monte Carlo simulations are carried out by performing the LCC analysis multiple times (10,000 times for each equipment class for this rulemaking). Each simulation has one particular set of inputs. The inputs are chosen from their respective probability distributions. For example, there are 50 states in the United States and the probability of choosing one state for a simulation is based on the population of the state. The higher the population of a state, the higher the probability of choosing that state for a particular simulation. Similarly, the equipment lifetime is specified by Weibull distribution curves with mean equipment lifetime of 10 or 15 years. Crystal Ball chooses the equipment lifetime for any particular simulation based on the Weibull probability distribution curve. Thus, each Monte Carlo simulation is a random combination of input values, with each input value chosen according to its respective probability distribution. That is, during a single trial, Crystal Ball 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 8D. ESTIMATION OF POTENTIAL EQUIPMENT PRICE TRENDS FOR COMMERCIAL REFRIGERATION EQUIPMENT

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APPENDIX 8D. ESTIMATION OF POTENTIAL EQUIPMENT PRICE TRENDS FOR COMMERCIAL REFRIGERATION EQUIPMENT

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 2011 (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, DOE stated that it may consider improving regulatory analysis by addressing equipment price trends. 76 FR 9696. Consistent with the NODA, DOE examined historical producer price indices for commercial refrigeration equipment.

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. 76 FR 9696 (Feb. 22, 2011). 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," available at http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/experience_curve_appliance_price_forecasting_3-16-11.pdf, summarizes the data and literature currently available to DOE that is relevant to price forecasts for selected appliances and equipment.

The extensive literature on the "learning" or "experience" curve phenomenon is typically based on observations in the manufacturing sector.[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:

$$Y = aX^{-b}$$

Eq. 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:

$$LR = 1 - 2^{-b}$$

Eq. 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 using the Bureau of Labor Statistics' (BLS) Producer Price Index (PPI) and gross domestic product (GDP) deflator, available from the Bureau of Economic Analysis (BEA). The PPI data for commercial refrigerators and related equipment is available for 1978–2012 and is used to represent aggregate commercial refrigeration equipment prices. Figure 8D.1.1 shows the PPI data series used.

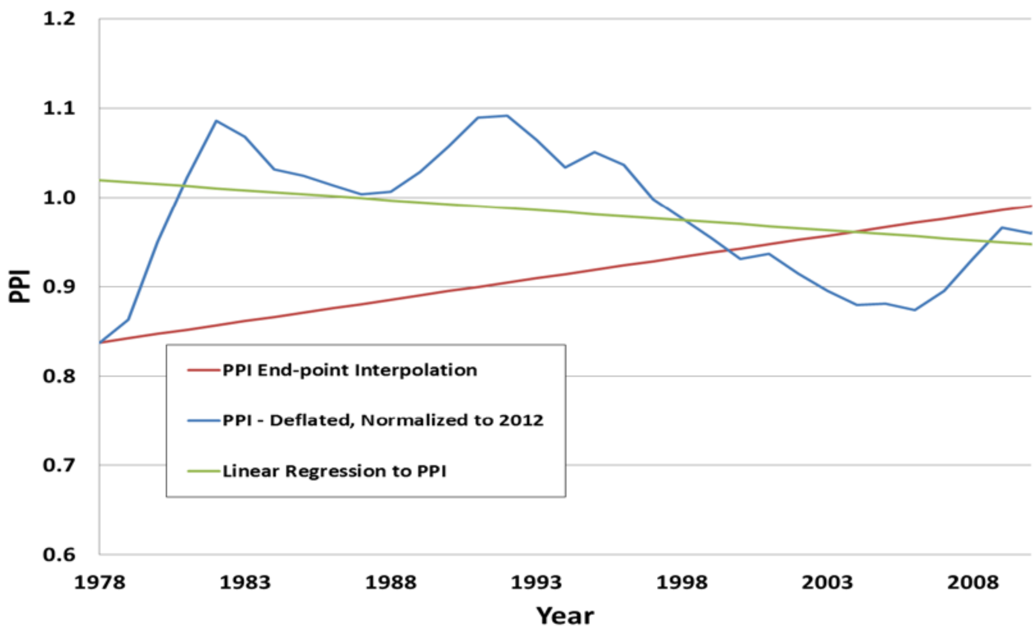

Figure 8D.1.1 PPI Data for Commercial Refrigeration Equipment

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 because nearly all commercial refrigeration equipment is shipped to commercial customers and use of the GDP deflator was consistent with energy price forecast assumptions by Energy Information Administration (EIA).

8D.2 DATA EVALUATION AND ANALYSIS

Figure 8D.1.1 shows an apparent price trend in commercial refrigeration equipment that is trending slightly upward from 1978 to 2012, but shows a decrease in the real PPI during two significant periods of time: 1982 to 1988 and1992 to 2004. Based on these price trends, DOE expects that the PPI is likely to resume a downward trend in the future.

To perform an experience curve fit, DOE assembled a time-series of annual shipments for 1950 to 2009 for commercial refrigeration equipment (for calculating cumulative production) based on shipments data for 2009.

Projected shipments after 2009 were obtained from the base-case projections made for the national impact analysis (see chapter 10 of this technical support document). Projected annual shipments are depicted in Figure 8D.2.1.

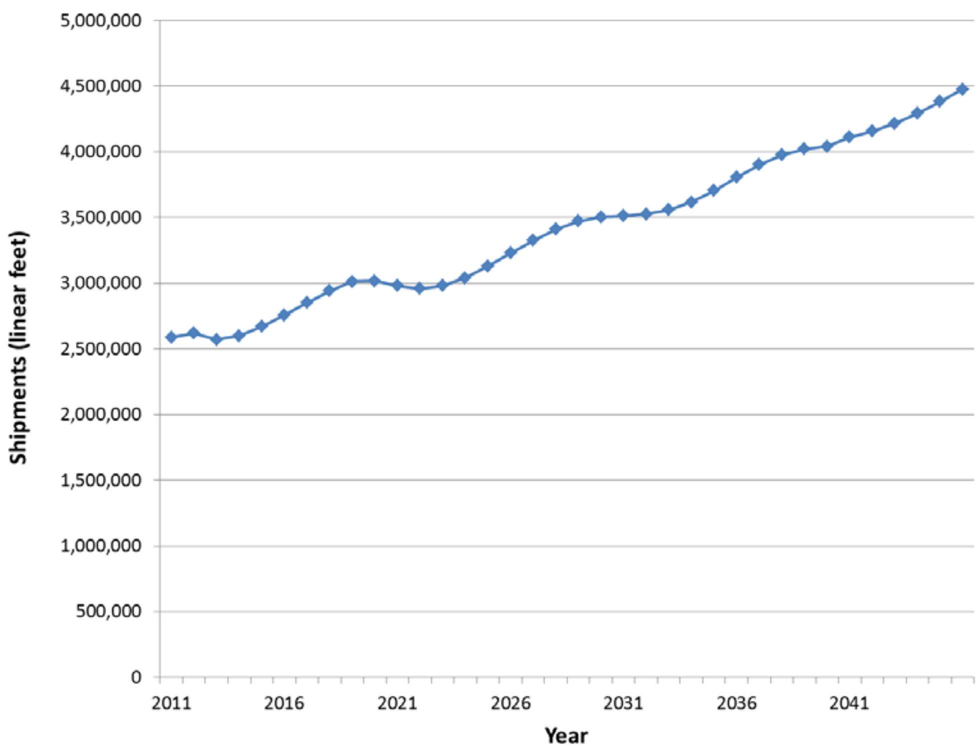

Figure 8D.2.1 Projected Annual Shipments for Commercial Refrigeration Equipment

To estimate potential product price trends, DOE performed a least-squares power-law fit on the commercial refrigeration equipment price index versus cumulative shipments. The form of the fitting equation is:

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

Eq. 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 the Eq. 8D.3, DOE estimated the learning rate (defined as the fractional reduction in price expected from each doubling of cumulative production) as 3 percent.

With cumulative shipments through 2046 projected to reach 215.3 million linear feet (compared with 92.4 million linear feet in 2010), the modeled trend predicts a drop of 3.3 percent in real price compared to the 2012 prices in the economy as a whole. Figure 8D.2.2 shows the model fit for the projected values for the period after 2009.

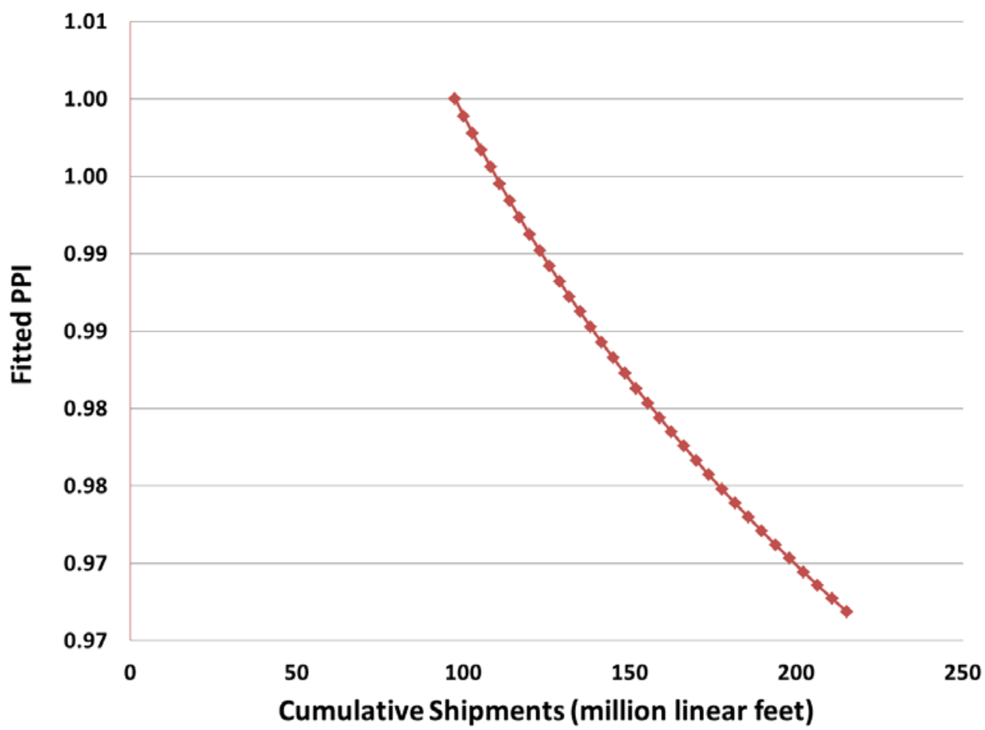

Figure 8D.2.2 Model Fit for Commercial Refrigeration Equipment

8D.3 REFERENCES

1. Weiss, M., Junginger, H.M., Patel, M.K., Blok, K., (2010). A Review of Experience Curve Analyses for Energy Demand Technologies. *Technological Forecasting & Social Change*. 77:411-428.

CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

Commercial refrigeration equipment shipment numbers are key inputs to the national energy savings analysis, net present value calculations, and the manufacturer impacts analysis. This chapter describes the U.S. Department of Energy's (DOE's) methodology for estimating commercial refrigeration equipment shipments and annual equipment stocks for 2009 through 2046.

The Shipments Model results are driven primarily by historical shipments data for the 25 primary classes of commercial refrigeration equipment under consideration. Figure 9.1.1 outlines the structure of the Shipments Model.

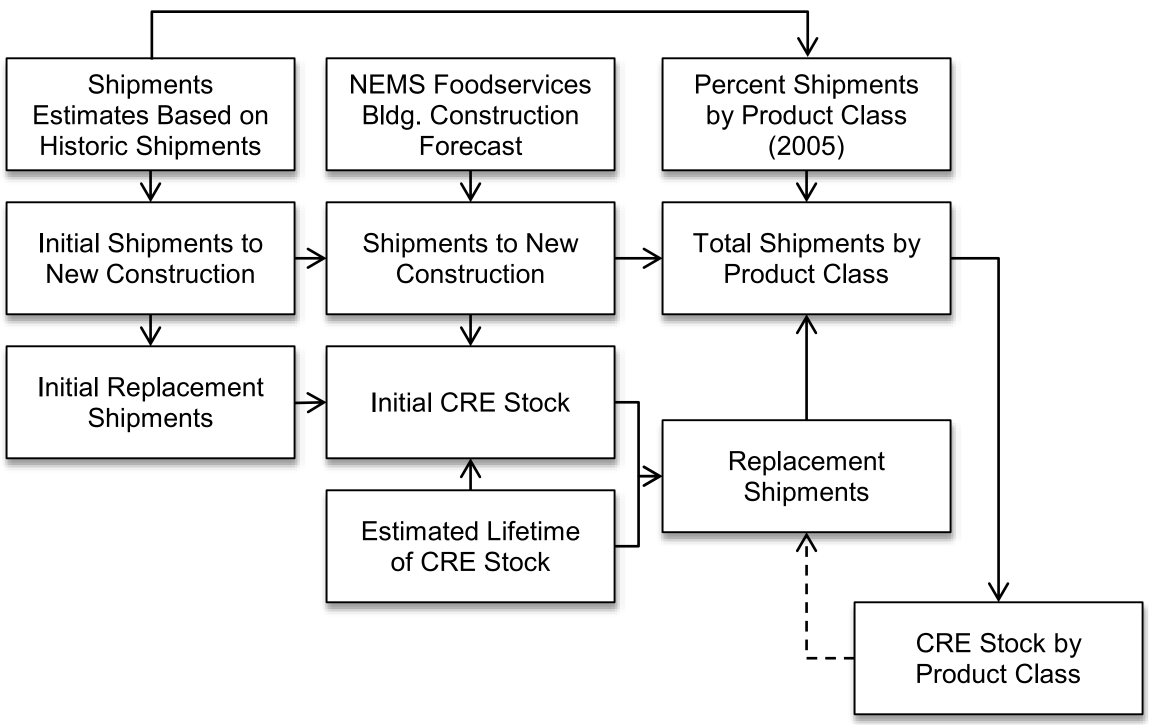

Figure 9.1.1 Flow Chart Showing Inputs to the Shipments Model

The model assumes that, in each year, a given unit that is part of the existing commercial refrigeration equipment stock either ages by one year or breaks. Broken equipment is replaced. In addition, new equipment can be installed into new commercial floor space, and old equipment can be removed through demolitions (not shown in the diagram).

Section 9.2 presents the mathematical formulation of the model, section 9.3 describes the data input to the model, and section 9.4 presents the results for the base-case level scenario and discusses the development of higher standard scenarios.

9.2 SHIPMENTS MODEL EQUATIONS

The Shipments Model is a description of commercial refrigeration equipment stock flows as a function of year and age. While 25 equipment classes are examined in the model, it is assumed that there is no coupling between the shipments of the various equipment classes, so the equations are applicable to each equipment class independently.

DOE formulated the Shipments Model equations as updates of the distribution of stock in year t to year $t+1$ as a function of age a. DOE first converted the equipment units to linear feet of refrigerator/freezer space using national statistics on sales of equipment and representative equipment size (linear feet). DOE used this calculation of existing stock, and the average age of the equipment, as a basis for calculating replacement sales. Then, DOE subtracted replacement sales from historical total sales statistics to calculate new sales of commercial refrigeration equipment. DOE forecasted new sales as a function of new construction of retail food sales and foodservice space. Sales of new and replacement equipment were recorded by the year sold, and each annual vintage was depreciated over the estimated life of the equipment. Sales in each year were allocated to the 25 equipment classes in proportion to their relative historical sales.

9.2.1 Shipments Model

DOE uses two commercial refrigeration equipment stock categories. The category $U_0(t,a)$ is the stock of existing units. All units are assumed to have had normal repairs that do not affect the lifetime of the equipment.

As discussed in chapter 8 of this technical support document (TSD), the average lifetime of a unit is estimated to be 10 years for remote condensing display cases in large grocery stores and supermarkets and all self-contained equipment, and 15 years for remote condensing display cases in small grocery stores such as convenience stores. Also, the average age of the initial existing stock of equipment is assumed to be 5 years, based on the 10-year lifetime of a unit of equipment and annual replacements going back 10 years. The total stock of age a in a given year t is represented by

$$U(t,a) = U_0(t,a)$$

Eq. 9.1

Where:

$U(t,a)$ = total stock of age a in a given year t,
$U_0(t,a)$ = stock of existing units,
a = age of stock (year), and
t = year.

The shipments of new stock in a given year are $Uship(t)$. By definition, the age of the equipment is zero in the year that it is shipped, so that $Uship(t) = U(t,0)$.

9.2.2 Stock Events

In the transition from year t to year $t+1$, two things could happen to the stock of commercial refrigeration equipment: (1) existing equipment could break or be removed during a store renovation and be replaced; or (2) the stock could simply age by 1 year.

In the model, early replacements (*i.e.*, existing equipment that is replaced before it is broken) are not considered, and all broken equipment is assumed to be replaced. The following sections present the equations used to represent each possible event.

9.2.2.1 Replacing Equipment

DOE determines the probability that commercial refrigeration equipment of age a from stock U_0 will break or will be replaced using a Weibull survival distribution function $PB_0(a) = W(8,10.62)$ for large food sales and for foodservice applications. This results in a 10-year average lifetime, a minimum lifetime of about 7 years, and a maximum lifetime of about 13 years, consistent with industry comments. The function $PB_0(a) = W(8,16)$ was used for small food sales outlets (*i.e.*, convenience stores with and without gas stations). This results in an average lifetime of 15 years, with a minimum of about 9 years and a maximum of about 20 years, again consistent with industry comments. Similarly, the probability that equipment of age a from stock U_1 will break is given by the same function $PB_1(a)$. These probabilities do not depend on the model year t. DOE defines the quantities of replaced equipment as

$$UB(t,a) = PB_0(a) \times U_0(t,a)$$

Eq. 9.2

Where:

$UB(t,a)$ = quantity of replacement units of age a in year t,
$PB_0(a)$ = probability that stock of existing units of age a will break or will be replaced,
$U_0(t,a)$ = stock of existing units of age a in year t,
a = age of stock (years), and
t = year.

9.2.2.2 New Equipment

The model assumes that new commercial refrigeration equipment is purchased to replace the existing units at the end of their lifetime, and for service in new buildings. Available information suggests that the purchase of new equipment for use in new buildings is driven by the rate of construction of food sales and foodservice floor space.

By definition, for each type of building:

$$EFS(t+1) = EFS(t) + NFS(t) - DFS(t)$$

Eq. 9.3

Where:

$EFS(t)$ = the square footage of existing floor space in year *t*,
$NFS(t)$ = the square footage of new floor space added in year *t*, and
$DFS(t)$ = the square footage demolished in year *t*.

The linear footage of units installed in new buildings is

$$UN(t) = UN(t\text{-}1) \times A_0 \times NFS(t) / NFS(t\text{-}1)$$

Eq. 9.4

Where:

$UN(t)$ = the number of units installed, in linear feet, in new buildings in year *t*, and
A_0 = an overall scale factor that accounts for the number of units covered by the standard, which are not used in all commercial building types; the default value for A_0 is 1.0.

DOE has no information on the variation in the market saturation of commercial refrigeration equipment by building type or over time. Therefore, in the model, the purchase of new equipment is driven by the construction of new floor space and the assumption that broken or removed equipment is replaced on a one-to-one basis.

9.3 DATA INPUTS

9.3.1 Historical Shipments

Shipments data for commercial refrigeration equipment could not be obtained in a complete form from any one source; therefore, DOE used data from multiple sources to estimate shipments and to compare and cross-verify the shipments data from one source to another. The major sources were 2005 shipments data provided by the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) as part of its comments to the 2009 rulemaking Framework document (Docket No. EERE-2006-STD-0126, ARI, No. 7, Exhibit B at p. 1); *Commercial Refrigeration Equipment to 2014* by Freedonia Group, Inc. (the Freedonia 2010 report)[1]; *2008 Size and Shape of Industry* by the North American Association of Food Equipment Manufacturers (NAFEM 2008 report)[2] and *2010 Size and Shape of Industry* by the North American Association of Food Equipment Manufacturers (NAFEM 2010 report)[3]; and *Energy Savings Potential and R&D Opportunities for Commercial Refrigeration* prepared by Navigant Consulting, Inc., for DOE (NCI 2009 report).[4] Further details about these data sources can be obtained from TSD chapter 3.

The AHRI 2005 shipments data was a compilation of shipments numbers provided by AHRI members, and as such did not represent the entire commercial refrigeration equipment market. However, the AHRI 2005 shipments data contained shipments explicitly broken down by DOE equipment class. The Freedonia 2010 report provided shipments data in terms of total dollar sales and number of units shipped. Shipments were split by market type (*e.g.*, foodservice industry, food and beverage retail industry) and by certain equipment types (*e.g.,* open display cases, reach-ins). The NAFEM 2008 and 2010 reports provided shipment numbers and dollar sales values for refrigeration and ice machines used in the foodservice industry. Reach-in refrigerators and freezers, chest freezers, milk coolers, and ice-cream storage and dipping cabinets make up the majority of the commercial refrigeration equipment used in the foodservice industry.

Because complete shipments data could not be obtained from a single source, DOE compiled data from all of the aforementioned sources and developed the 2009 shipments numbers using some basic assumptions. The Freedonia 2010 report contains historical data used to derive a year-to-year percentage change in the total commercial refrigeration equipment sales. DOE assumed that subsequent years' shipments of the equipment reported in the 2005 AHRI summary grew at the year-to-year growth rates reported by Freedonia, and used the percentage changes from the Freedonia 2010 report to derive the 2009 AHRI shipments estimates from the AHRI reported shipments for the year 2005.

The 2009 shipments numbers derived from the 2005 AHRI shipments data were modified for certain equipment classes using shipments data obtained from the other sources. Shipments for equipment classes VCS.SC.M and VCS.SC.L were obtained from estimates from the NAFEM 2008 and 2010 reports. (Chapter 3 of this TSD defines the acronyms used for the equipment classes in this section.) The Freedonia 2010 report provided shipments for open display cases that operate at normal (medium) and low temperatures, and closed display cases that operate at normal (medium), low, and ice-cream temperatures. These aggregate numbers could not be further split into the equipment classes. For example, the open display cases could not be split into VOP, SVO, and HZO cases. However, the aggregate shipments numbers for normal and low-temperature display cases compared reasonably well with the corresponding aggregate shipments numbers from 2005 AHRI shipments data. While the aggregate shipments numbers for ice-cream display cases compared well for both the 2005 AHRI shipments data and Freedonia 2010 report, the 2005 AHRI shipments number of 9,056 units for HCT.SC.I seemed too high, especially considering the fact that the shipments number for HCT.SC.L is zero. HCT.SC.L equipment is predominantly used in ice-cream stores in the form of ice-cream dipping cabinets. While this equipment is advertised as ice-cream dipping cabinets, the operating temperature range is typically -10 °F to 5 °F, which is above the ice-cream rating temperature of -15 °F. DOE assumed that the AHRI shipments numbers for HCT.SC.L may have been subsumed into the HCT.SC.I numbers. DOE allocated half of the shipments from HCT.SC.I to HCT.SC.L. These numbers compared reasonably well to the ice-cream cabinets, freezer, and dispensers numbers from the NAFEM reports. Shipments for equipment class PD.SC.M were obtained based on estimates from the NCI 2009 report. However, based on inputs from other sources, the shipments number for PD.SC.M units was increased by 25 percent compared to the estimates in the NCI 2009 report.

As previously mentioned, shipments by equipment class were available only from the 2005 AHRI data. To allocate the shipments to different equipment classes from the other sources, DOE made assumptions about the definitions of the equipment types and the market share split for certain equipment classes. Shipments numbers and assumptions have been withheld because the NAFEM reports and Freedonia 2010 report are not public documents and are available only for purchase.

9.3.2 Historical Shipments and Projected Building Stock Additions

Historical linear feet of shipped units depicts the annual amount of commercial refrigeration equipment capacity shipped and is an alternative way to express shipments data. DOE determined the linear feet shipped for any given year by multiplying each unit shipped by its associated average length, and then summing all the linear footage values.

DOE converted the estimated 2009 shipments data in each equipment class to percentages of total shipped linear feet of commercial refrigeration equipment for use in the Shipments Model. This established the commercial refrigeration equipment market share attributed to each equipment class. DOE calculated the percent of shipped linear footage by dividing the linear footage shipped for each equipment class by the overall linear footage shipped for all commercial refrigeration equipment covered in this rulemaking.

Table 9.3.1 summarizes DOE's estimated division of historical annual shipments into new and replacement categories by building type. The distributions shown in Table 9.3.1 are the result of several discrete steps. First, equipment types were identified by the type of business they generally serve. For example, vertical open cases with remote compressors are generally associated with large grocers and multi-line retail stores. Remote condensing equipment is generally associated with large food sales stores, while self-contained units are associated with food service and convenience or small food sales stores. When there was no strong association between the building type and equipment class, equipment was distributed across broader classes. Second, a ratio of new versus replacement was developed based on commercial floor space estimates (floor space estimates are discussed in section 9.3.3). Using the expected useful life of commercial refrigeration equipment and commercial floor space stock, additions, and retirements, ratios were developed that yielded values for the amount of new versus replacement stock for use in this analysis. Using these and related factors (*e.g.,* the division of foodservice into the three building types: limited service restaurants, full-service restaurants, and other), DOE distributed commercial refrigeration equipment shipments among building types and new versus replacement shipments as shown in Table 9.3.1.

Table 9.3.1 Estimated Distribution of 2009 Linear Feet of Commercial Refrigeration Equipment Shipments Among New vs. Replacement Equipment

Building Type	Replacement	New	Total
Large Grocery / Multi-Line Retail	30.5%	8.6%	39.1%
Small Grocery / Convenience	14.6%	4.1%	18.7%
Limited Service Restaurants	9.5%	3.3%	12.7%
Full Service Restaurants	9.8%	3.4%	13.2%
Other	12.1%	4.2%	16.3%
Total	76.4%	23.6%	100.0%

Table 9.3.2 shows the forecasted square footage of new construction used to scale annual new commercial refrigeration equipment shipments. As the data in Table 9.3.2 show, forecasted square footage additions to the building stocks vary from year to year, with the first few years exhibiting lower levels of growth due to the lingering impacts of the U.S. economic recession. The forecasted commercial refrigeration equipment shipments therefore show some variability as well, tracking the forecasted square footage floor space additions. The annual floor space additions expressed as a percentage of total surviving floor space, averaged over the last 10 years

of the *Annual Energy Outlook* (*AEO*) forecast (2031 through 2040), were used to extend the *AEO* forecast out until the year 2046 in order to develop the full 30-year forecast needed for the national impacts analysis (see TSD chapter 10).

Table 9.3.2 *AEO2013* Forecast of New Food Sales and Foodservice Square Footage

Year	New Construction *million ft²*	
	Foodservice	Food Sales
2009	47.715	34.070
2012	31.455	22.149
2017	49.076	34.496
2020	47.617	33.447
2025	47.522	33.416
2030	53.630	37.836
2035	55.536	39.107
2040	55.814	39.243
Annual Growth Factor, 2031-2040	2.41%	2.27%

Source: U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2013*.

DOE used the AHRI shipments data to derive shipped linear footage for each of the 25 primary equipment classes. Table 9.3.3 presents the representative equipment class lengths used for the conversion of per-unit shipments to linear footage within each equipment class.

Table 9.3.3 Equipment Linear Dimensions Assumed for Shipments Analysis

Equipment Class	Assumed Length *ft*	Basis
VOP.RC.M	10	Average of 8 ft and 12 ft, manufacturer interviews
VOP.RC.L	10	Average of 8 ft and 12 ft, manufacturer interviews
VOP.SC.M	4	Baseline equipment used for engineering analysis
SVO.RC.M	10	Average of 8 ft and 12 ft, manufacturer interviews
SVO.SC.M	4	Baseline equipment used for engineering analysis
HZO.RC.M	10	Average of 8 ft and 12 ft, manufacturer interviews
HZO.RC.L	10	Average of 8 ft and 12 ft, manufacturer interviews
HZO.SC.M	4	Baseline equipment used for engineering analysis
HZO.SC.L	4	Baseline equipment used for engineering analysis
VCT.RC.M	10	Average of 3-door and 5-door (30 in. per door), manufacturer interviews
VCT.RC.L	10	Average of 3-door and 5–door (3 in. per door), manufacturer interviews
VCT.SC.M	4	Engineering estimate*
VCT.SC.L	3.5	Average of 1-door and 2-door freezer
VCT.SC.I	5	Baseline equipment used for engineering analysis
VCS.SC.M	4	Engineering estimate
VCS.SC.L	3.5	Average of 1-door and 2-door freezer
VCS.SC.I	5	Baseline equipment used for engineering analysis
HCT.SC.M	3.0	Engineering estimate*
HCT.SC.L	3.0	Engineering estimate*
HCT.SC.I	3.4	Baseline equipment used for engineering analysis
HCS.SC.M	4.0	Engineering estimate*
HCS.SC.L	5.0	Engineering estimate*
SOC.RC.M	8	Average of 4 ft, 8ft, 12 ft, all common equipment lengths
PD.SC.M	2.5	Baseline equipment used for engineering analysis
SOC.SC.M	5	Engineering estimate*

*For equipment classes that exhibit a wide range of equipment lengths in the market, DOE assumed a value for equipment length based on the best engineering judgment.

DOE then calculated the annual linear footage shipped for each of the 25 equipment classes. The shipments analysis relies on the 25 equipment classes to represent the commercial refrigeration equipment market. Table 9.3.4 shows the fraction of the linear footage shipped by each of these 25 equipment classes.

Table 9.3.4 Percent of Shipped Linear Feet of Commercial Refrigeration Equipment

Equipment Class*	Percentage of Linear Feet Shipped*		Equipment Class	Percentage of Linear Feet Shipped*
VOP.RC.M	11.59%		SVO.SC.M	1.23%
VOP.RC.L	0.61%		SOC.RC.M	2.34%
VOP.SC.M	0.82%		HZO.RC.M	1.43%
VCT.RC.M	0.87%		HZO.RC.L	4.49%
VCT.RC.L	12.11%		HZO.SC.M	0.11%
VCT.SC.M	5.46%		HZO.SC.L	0.22%
VCT.SC.L	0.27%		HCT.SC.M	0.07%
VCT.SC.I	0.30%		HCT.SC.L	0.43%
VCS.SC.M	22.11%		HCT.SC.I	0.48%
VCS.SC.L	11.25%		HCS.SC.M	5.01%
VCS.SC.I	0.07%		HCS.SC.L	0.65%
SVO.RC.M	9.30%		PD.SC.M	8.58%
SOC.SC.M	0.17%			

*Numbers do not add to 100% because secondary equipment classes (chapter 5) are excluded from the table.

9.3.3 Commercial Floor Space and Market Saturation

The amount of commercial floor space is the main driver for commercial refrigeration equipment shipments and is appropriately one of the basic inputs into the Shipments Model. As discussed in section 9.2.2, the model divides commercial space into two components: space from new construction floor space (*NFS*), and existing floor space (*EFS*).

For this analysis, commercial square footage with commercial refrigeration equipment refers to both new and existing stock of buildings.

9.3.3.1 Floor Space – New Construction

DOE used the projected floor space construction after the year 2009 from the National Energy Modeling System projection underlying *AEO2013*.[5] DOE extracted annual estimates of new floor space additions from an *AEO2013* data file for the 2009 through 2040 period. As stated earlier, the last 10 years of the *AEO* forecast were used to develop growth rates used to extend the forecast to 2046.

The total value for the new length of equipment is the estimated total shipments in linear feet for 2009, divided between the food sales and foodservice sectors and multiplied by indexes of new construction of square feet for each building type. The index for each building type was developed by dividing floor space projections in each future year by the value from the prior year. All existing display space is presumed to be replaced when demolished.

9.3.3.2 Market Shipments

DOE used the above shipments data to estimate the market shipments in year t of each commercial refrigeration equipment class *y*, *MKTSHIP(t,y)*, defined in terms of linear feet of space occupied by the new and replacement shipments of equipment class *y*. Because the market share by percent of each equipment class shipments is relatively constant over time and the lifetime of each class remains same, the ratio of shipments of a specific equipment class indicates the market share for that class, *MKT(y)*. DOE estimated the *MKT(y)* for a particular equipment class to be a constant value equal to the average of the yearly percent historical shipments to that class. These percentages are reported in Table 9.3.4.

$$MKTSHIP(t, y) = MKT(y) \times (UN(t) + UB(t))$$

Eq. 9.5

Where:

MKTSHIP(t,y) = total market shipments, in linear feet of display space, of equipment class *y* in year *t*,
MKT(y) = percentage of total market shipments in equipment class *y* (%),
UN(t) = total shipments to new buildings in year *t*, and
UB(t) = total replacement shipments in year *t*.

9.3.4 Equipment Utility

The equipment utility is a measure of the economic value of a linear foot of commercial refrigeration equipment to the customer. This is the value associated with energy savings. Because there are insufficient historical data available on the commercial refrigeration equipment market to develop and calibrate a full supply and demand model, economic factors are used to calculate annualized cost and to calibrate market shares for the Shipments Model. These economic factors are discussed below.

9.3.5 Equipment Price

Equipment price is the price paid by the customer for a unit of commercial refrigeration equipment. It includes both the purchase price of the equipment and the installation costs. DOE converts the equipment price to a price per linear-foot-cooled based on the length of the equipment class.

As discussed in the engineering analysis (chapter 5) and the life-cycle cost and payback period analysis (chapter 8), equipment prices in this analysis are a function of energy efficiency level. DOE based equipment price projections on energy consumption level, but did not develop estimates of market trends in efficiency. DOE developed a mix of energy consumption levels for the base case (*i.e.*, the case without new energy conservation standards) and for each candidate standard level envisioned. The efficiency mixes are discussed in detail in chapter 10.

9.3.5.1 Operating Costs

Operating costs consist of maintenance, repair, and energy costs. A detailed description of all the operating costs can be found in chapter 8.

9.3.5.2 Discounted Costs

When purchasing commercial refrigeration equipment, a budget-conscious customer will consider the total lifetime cost of the equipment. Typically, these lifetime costs are discounted to represent the present value of these costs. DOE discounted the total operating costs (*i.e.*, maintenance, repair, and energy costs) over the full lifetime of the equipment. Commercial refrigeration equipment lifetimes range from 1 to as many as 20 years. However, based on discussions with industry, the typical lifetime of commercial refrigeration equipment is 10 years in large food retailers and 15 years in small retailers. This is because large grocery stores either undergo renovation or replace the refrigeration equipment for aesthetic reasons at roughly 10-year intervals, but small food retailers with fewer resources to direct towards capital improvements usually try to make their equipment last longer and update it less frequently (see chapter 8 for further details). Equipment life was modeled as 10 years in foodservice sectors for reasons similar to the large retailers.

9.4 RESULTS

Table 9.4.1 shows the shipments forecast for the commercial refrigeration equipment classes at the base-case energy consumption level (or Level 1) divided into new and replacement units for large and small food sales and foodservice outlets. Table 9.4.2 shows total shipments by equipment type.

Table 9.4.1 Forecasted Shipments of New and Replacement Commercial Refrigeration Equipment by Building Type, 2017–2046 (Base Case)

Building Type	Thousands of Linear Feet Shipped by Year and Equipment Class							
	2017	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**Total**
Large Grocery								
– New	253	237	245	278	287	288	314	8,276
– Replacement*	853	935	964	1,078	1,145	1,272	1,372	33,176
Small Grocery								
– New	121	118	118	133	138	138	151	3,963
– Replacement*	386	381	417	428	443	474	506	13,115
Foodservice								
– New	326	316	315	356	369	370	404	10,631
– Replacement*	882	993	1,039	1,193	1,286	1,456	1,590	36,899
Total	2,822	2,980	3,098	3,467	3,667	3,999	4,338	106,061

* Replacement includes equipment replaced from original stock (installed before the standards set by the current rulemaking takes effect) and the standards level equipment replaced in subsequent years.

Table 9.4.2 Forecasted Shipments for Commercial Refrigeration Equipment, 2017–2046, by Equipment Type (Base Case)

Equipment Class	Thousands of Linear Feet Shipped by Year and Equipment Class*								
	2017	2020	2025	2030	2035	2040	2045	2046	Cumulative
VOP.RC.M	327	346	359	402	425	463	503	513	12,287
VOP.RC.L	17	18	19	21	22	24	26	27	647
VOP.SC.M	23	24	25	28	30	33	36	36	870
VCT.RC.M	25	26	27	30	32	35	38	39	924
VCT.RC.L	342	362	375	420	444	484	525	537	12,847
VCT.SC.M	154	163	169	189	200	218	237	242	5,792
VCT.SC.L	8	8	8	9	10	11	12	12	289
VCT.SC.I	8	9	9	10	11	12	13	13	317
VCS.SC.M	624	661	685	766	811	884	959	979	23,447
VCS.SC.L	318	336	349	390	413	450	488	499	11,935
VCS.SC.I	2	2	2	3	3	3	3	3	78
SVO.RC.M	263	278	288	322	341	372	403	412	9,866
SVO.SC.M	35	37	38	43	45	49	53	54	1,302
SOC.RC.M	66	70	73	81	86	94	102	104	2,487
HZO.RC.M	40	43	44	50	52	57	62	63	1,516
HZO.RC.L	127	134	139	156	165	180	195	199	4,767
HZO.SC.M	3	3	3	4	4	4	5	5	112
HZO.SC.L	6	7	7	8	8	9	9	10	232
HCT.SC.M	2	2	2	2	3	3	3	3	73
HCT.SC.L	12	13	13	15	16	17	19	19	453
HCT.SC.I	14	14	15	17	18	19	21	21	514
HCS.SC.M	141	150	155	174	184	200	217	222	5,310
HCS.SC.L	18	19	20	22	24	26	28	29	686
PD.SC.M	242	256	266	297	315	343	372	380	9,101
SOC.SC.M	5	5	5	6	6	7	8	8	185
Total	2,821	2,987	3,097	3,466	3,666	3,998	4,337	4,429	106,034

*Values include only equipment classes modeled in the engineering, life-cycle cost, and national impact analyses.

As equipment purchase price increases with lower energy consumption levels, a drop in shipments could be expected relative to the base case. Although there is a provision in the Shipments Model spreadsheet for a change in shipments as the efficiency level increases (or energy consumption level decreases), DOE has no information with which to calibrate such a relationship. Therefore, for the notice of proposed rulemaking, DOE presumes that the shipments do not change in response to the higher efficiency levels that form potential candidate standard levels.

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

This chapter describes the method for estimating the magnitude and net present value (NPV) of future national energy savings (NES) from possible standards levels for commercial refrigeration equipment. Results of the national impact analysis (NIA) described in this chapter include NES, monetary value of energy savings to the nation as a result of standards, increased total installed costs to the nation as a result of standards, and the NPV of future savings (the difference between the present monetary values of energy savings and increased total installed costs).

The U.S. Department of Energy (DOE) determined both the NPV and NES for each candidate standard level (CSL) it considered for each of the 25 primary equipment classes of commercial refrigeration equipment analyzed in this rulemaking. Sections 10.2 and 10.3 present the definitions and the inputs to NES and NPV, respectively. Section 10.4 presents the results of the NIA. DOE performed all calculations using a Microsoft Excel spreadsheet, which is available at http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/52. Details and instructions for using the spreadsheet are discussed in appendix 10A of the technical support document (TSD).

10.2 NATIONAL ENERGY SAVINGS

10.2.1 National Energy Savings Definition

DOE calculates annual NES for a given year (denoted as *t*, below) as the difference between two scenarios: a base-case scenario without new energy conservation standards and standards-case scenarios with new energy conservation standards. Positive values of NES correspond to net energy savings (*i.e.*, national annual energy consumption (AEC) with standards is less than national AEC in the base case).

$$NES_t = AEC_{base,t} - AEC_{standards,t}$$

Eq. 10.1

Where:

NES_t = national energy savings in the year *t* (quadrillion British thermal units (quads)),
$AEC_{base,t}$ = annual national energy consumption in the year *t* in the base-case scenario (quads), and
$AEC_{standards,t}$ = annual national energy consumption in the year *t* in a standards-case scenario (quads).

Annual NES from each year, starting with the year when the standards that are the subject of this rulemaking become effective (2017), can be summed to calculate the cumulative NES (NES_{cum}).

$$NES_{cum} = \sum_t NES_t$$

Eq. 10.2

For each equipment class, DOE calculated the AEC for base-case and standards-case scenarios by multiplying the stock of commercial refrigeration equipment (by vintage) by the unit energy consumption (UEC) (also by vintage) as shown by the following equation:

$$AEC_t = \sum_V (STOCK_V \times UEC_V) \times src\_conv_t$$

Eq. 10.3

Where:

AEC_t = national annual energy consumption in the year t (quads), summed over vintages of commercial refrigeration equipment stock,
$STOCK_V$ = stock of commercial refrigeration equipment (millions of units) of vintage V surviving in the year for which DOE calculated annual energy consumption; vintages range from 1 to approximately 10 years (or 15 years for certain equipment and building types, see chapter 8 of the TSD), a function of an assumed 10-year (or 15-year) lifetime of the equipment,
UEC_V = annual unit energy consumption in kilowatt-hours (kWh) for equipment of vintage V,
src_conv_t = time-dependent conversion factor to convert from site energy to source energy (British thermal units per kilowatt-hour (Btu/kWh)), and
t = year of forecast.

The stock of commercial refrigeration equipment is dependent on annual shipments and the lifetime of the equipment. DOE acknowledges that the shipment projections under the standards-case scenarios could be lower than those in the base-case scenario, because the higher installed costs could cause some customers to forego or delay discretionary equipment purchases that are not occasioned by the need to replace failed equipment or to furnish a new building. However, DOE has no information that would allow a calculation of this effect, so shipments were assumed to be the same in both base-case and standards-case scenarios.

10.2.2 National Energy Savings Inputs

Table 10.2.1 lists the inputs for the determination of NES.

Table 10.2.1 National Energy Saving Inputs

Input
Annual Unit Energy Consumption (*UEC*)
Shipments
Equipment Stock ($STOCK_V$)
Site-to-Source Conversion Factor (*src_conv*)

10.2.2.1 Annual Unit Energy Consumption

The annual UEC is the site energy consumed by a commercial refrigeration unit in a given year. Because the equipment classes analyzed represent equipment sold across a range of sizes, DOE's "unit" in the NES is actually expressed as a linear foot of equipment in an equipment class and not an individual unit of commercial refrigeration equipment of a specific size. As described in this section, DOE determined annual forecasted shipment-weighted average equipment efficiencies that, in turn, enabled determination of shipment-weighted AEC values.

DOE did not have data on the market shares by efficiency level within each of the equipment classes. For this notice of proposed rulemaking (NOPR), DOE used the same methodology employed in the January 9, 2009 final rule to estimate market shares of each efficiency level within each equipment class. 74 FR at 1092. The methodology is a cost-based method consistent with the approaches that were used in the Energy Information Administration's (EIA's) National Energy Modeling System[1] (NEMS) and in the Canadian Integrated Modeling System (CIMS)[a,2] for estimating efficiency choices within each equipment class. DOE then extrapolated future scenarios of the equipment efficiency for the base case and standards cases using the same cost-based method. The difference in equipment efficiency between the base case and standards case was the basis for determining the reduction in UEC resulting from new standards.

The market share for each equipment class by efficiency level is defined as *EFF_Level_Share(i,y)*, for each equipment class, *y*, at each efficiency level, *i*. Because DOE had no information regarding future changes in market shares between equipment classes, DOE assumed the market share for a particular equipment class to be constant over time. DOE calculated the *EFF_Level_Share(i,y)* for each efficiency level *i* using the following formula, based on the relative annualized cost of each efficiency level.

$$EFF\_Level\_Share(i,y) = \sum_{j=1}^{m} b_j \times \frac{\left(IC_{(i,y)} \times \frac{r_j}{1-(1+r_j)^{-n}} + OC_{(i,y)} \right)^{-v}}{\sum_{i=1}^{k} \left(IC_{(i,y)} \times \frac{r_j}{1-(1+r_j)^{-n}} + OC_{(i,y)} \right)^{-v}}$$

Eq. 10.4

Where:

EFF_Level_Share(i,y) = the market share of efficiency level *i* for equipment class *y*,
IC(i, y) = installed cost of equipment class *y* with efficiency level *i, k* is the number of efficiency levels in equipment class *y*,
OC(i,y) = annual operating cost (maintenance, repair, and energy cost) of equipment class *y* with efficiency level *i*,
k = number of efficiency levels in the equipment class,
r_j = private, risk-adjusted discount rate for risk class *j*, which is derived for each class by adding a time preference premium to the measure of risk-free real rate of return in the marketplace (6.41 percent historical 40-year geometric average long-term Treasury bond rate minus long-term inflation rate of 3.68 percent, or 2.72 percent),
b_j = market share of equipment users with risk class *j, j* = 1 to *m*,
v = risk penalty factor (also known as a measure of market heterogeneity), and
n = equipment lifetime.

[a] The CIMS Model was originally known as the Canadian Integrated Modeling System, but as the model is now being applied to other countries, the acronym is now used as its proper name.

The components for *IC* and *OC* come from the same inputs as the life-cycle cost (LCC) analysis (see TSD chapter 8). The annualization factor $r_j/(1-(1+r_j)^{-n})$ converts installed cost into its annual equivalent, so that market shares are based on the relative annual costs of each efficiency level, with (generally) higher annualized costs of higher efficiency levels leading to lower relative market shares. For each risk class r_j, Table 10.2.2 displays the implied discount rates taken from the NEMS commercial model. These, combined with the default value of v = 10, taken from the CIMS, and equipment lifetimes, were used to distribute equipment shipments across efficiency levels.

Table 10.2.2 Risk Premiums by Risk Class (*j*) Derived from the NEMS Commercial Model

Percentage of Users in Class	Time Preference Premium	Implied Real Discount Rate
0.3%	0.0%	2.72%
0.4%	6.5%	9.22%
9.7%	15.0%	17.72%
16.9%	25.0%	27.72%
21.5%	45.0%	47.72%
24.7%	100.0%	102.72%
26.5%	1000.0%	1002.72%
100%		

Source: NEMS Commercial Model

Table 10.2.3 provides estimated base-case market shares of efficiency levels for each of the 25 equipment classes analyzed in this rulemaking.

DOE used a “roll-up” method to obtain the market share of the efficiency levels in the standards-case scenarios. In the roll-up method, the market shares of all efficiency levels below the efficiency level corresponding to the standards-case scenario would be reassigned to the efficiency level corresponding to the standards-case scenario. For example, if a Level 4 standard were imposed in 2017 on the VOP.RC.M equipment class (vertical open refrigerator connected to a remote condensing unit), then the market shares for Levels 1, 2, and 3 would be assigned to Level 4. This would result in a market share of 85.1 percent (24.3 percent + 24.0 percent + 23.4 percent + 13.4 percent) from the first four columns of the first row in Table 10.2.3) for Level 4, beginning in 2017. The market shares for Levels 5–8 would not be affected because the market already has a choice of that equipment with Level 4 also available. DOE assumed that the standard level (Level 4) would not affect the relative attractiveness of equipment with efficiencies higher than the standard level.

Table 10.2.3 Market Shares of Efficiency Level, Base Case

Equipment Class	Shipment-Weighted Market Shares by Efficiency Level*,**							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	24.3%	24.0%	23.4%	13.4%	12.8%	2.0%	NA	NA
VOP.RC.L	26.0%	26.1%	23.2%	22.4%	2.2%	NA	NA	NA
VOP.SC.M	19.1%	19.0%	18.8%	18.1%	11.3%	10.7%	3.1%	NA
VCT.RC.M	18.8%	18.8%	15.9%	15.5%	14.8%	14.5%	1.7%	NA
VCT.RC.L	19.5%	20.4%	20.0%	19.4%	19.0%	1.8%	NA	NA
VCT.SC.M	16.7%	17.4%	15.4%	13.0%	12.6%	11.7%	11.5%	1.7%
VCT.SC.L	10.5%	13.2%	16.4%	16.2%	14.4%	14.2%	13.1%	2.0%
VCT.SC.I	16.4%	18.1%	17.8%	15.9%	15.5%	14.8%	1.5%	NA
VCS.SC.M	13.1%	14.9%	15.0%	15.0%	14.6%	14.0%	12.6%	0.8%
VCS.SC.L	12.1%	15.1%	15.3%	15.4%	14.3%	13.9%	13.3%	0.6%
VCS.SC.I	16.7%	16.8%	17.4%	17.0%	16.0%	15.4%	0.7%	NA
SVO.RC.M	24.5%	24.5%	22.2%	13.2%	12.6%	3.0%	NA	NA
SVO.SC.M	19.5%	19.5%	18.5%	18.0%	10.8%	10.1%	3.7%	NA
SOC.RC.M	17.7%	17.8%	17.8%	14.5%	14.1%	12.7%	5.4%	NA
HZO.RC.M	78.4%	21.6%	NA	NA	NA	NA	NA	NA
HZO.RC.L	86.2%	13.8%	NA	NA	NA	NA	NA	NA
HZO.SC.M	25.4%	25.4%	25.0%	21.9%	2.4%	NA	NA	NA
HZO.SC.L	71.8%	28.2%	NA	NA	NA	NA	NA	NA
HCT.SC.M	14.8%	15.4%	15.6%	15.7%	13.4%	12.8%	11.0%	1.4%
HCT.SC.L	12.3%	13.3%	13.6%	15.8%	15.6%	15.0%	13.2%	1.2%
HCT.SC.I	25.6%	25.8%	25.1%	22.3%	1.1%	NA	NA	NA
HCS.SC.M	17.2%	17.5%	17.2%	16.8%	15.9%	13.3%	2.1%	NA
HCS.SC.L	16.2%	17.0%	17.2%	17.1%	16.6%	14.5%	1.5%	NA
PD.SC.M	14.0%	17.2%	16.1%	15.8%	15.3%	11.0%	9.7%	1.0%
SOC.SC.M	14.7%	15.1%	15.1%	15.0%	12.5%	12.1%	11.0%	4.6%

* Shares may not add to 100% exactly due to rounding.
** A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.

Table 10.2.4 provides the annual UEC values for each efficiency level for all 25 primary equipment classes obtained from the LCC analysis (chapter 8 of the TSD). Since the equipment is available in various sizes within each equipment class, DOE used a linear foot of equipment as the unit measure for commercial refrigeration equipment. Therefore, the UEC values are expressed in kilowatt-hour per linear foot per year (kWh/linear foot/year). The UEC value multiplied by the length of a piece of equipment gives the average AEC of that piece of equipment. DOE combined the UEC values in Table 10.2.4 with the market shares of efficiency levels (base-case scenario) in Table 10.2.3 to obtain shipment-weighted UEC values for each efficiency level in the base-case scenario, presented in the column titled "Level 1" in Table 10.2.5. The market shares of efficiency levels in the standards-case scenarios were obtained by the roll-up scenario (described above in this section) and combined with the UEC values in Table 10.2.4 to obtain the shipment-weighted UEC values at all the standards-case scenarios, presented in columns titled "Level 2" through "Level 8" in Table 10.2.5.

Table 10.2.4 Average Annual Unit Energy Consumption per Linear Foot by Efficiency Level

Equipment Class	Average Annual Unit Energy Consumption by Efficiency Level* *kWh/linear foot/year*							
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**
VOP.RC.M	1,453	1,425	1,348	1,086	1,080	1,066	NA	NA
VOP.RC.L	3,292	3,231	3,073	3,057	3,007	NA	NA	NA
VOP.SC.M	2,800	2,771	2,740	2,701	2,437	2,430	2,415	NA
VCT.RC.M	466	446	232	180	173	171	158	NA
VCT.RC.L	1,118	953	892	876	868	827	NA	NA
VCT.SC.M	748	613	331	263	254	242	241	217
VCT.SC.L	2,360	1,745	1,094	1,078	1,009	1,003	980	938
VCT.SC.I	1,758	1,492	1,481	1,401	1,389	1,370	1,304	NA
VCS.SC.M	361	205	192	187	176	163	146	113
VCS.SC.L	892	624	589	574	547	540	532	463
VCS.SC.I	1,623	1,621	1,548	1,538	1,510	1,497	1,403	NA
SVO.RC.M	1,107	1,098	1,030	843	839	829	NA	NA
SVO.SC.M	2,439	2,434	2,349	2,314	2,125	2,120	2,110	NA
SOC.RC.M	794	779	760	621	618	613	606	NA
HZO.RC.M	439	431	NA	NA	NA	NA	NA	NA
HZO.RC.L	1,007	980	NA	NA	NA	NA	NA	NA
HZO.SC.M	1,350	1,347	1,333	1,322	1,302	NA	NA	NA
HZO.SC.L	2,748	2,729	NA	NA	NA	NA	NA	NA
HCT.SC.M	219	195	180	166	80	72	64	48
HCT.SC.L	497	434	394	176	170	164	150	114
HCT.SC.I	352	343	328	305	227	NA	NA	NA
HCS.SC.M	64	57	52	48	44	36	21	NA
HCS.SC.L	183	163	150	140	127	111	64	NA
PD.SC.M	1,009	569	326	322	316	256	239	207
SOC.SC.M	961	853	822	815	670	666	660	651

* A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.

Table 10.2.5 Shipment-Weighted Average Annual Energy Consumption per Linear Foot by Efficiency Level

Equipment Class	Shipment-Weighted Average Annual Energy Consumption by Standard Level* *kWh/linear foot/year*							
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**
VOP.RC.M	1,317	1,310	1,273	1,085	1,080	1,066	NA	NA
VOP.RC.L	3,166	3,150	3,068	3,056	3,007	NA	NA	NA
VOP.SC.M	2,673	2,667	2,655	2,633	2,435	2,429	2,415	NA
VCT.RC.M	289	286	205	177	172	171	158	NA
VCT.RC.L	940	908	883	874	867	827	NA	NA
VCT.SC.M	408	386	289	256	250	241	240	217
VCT.SC.L	1,267	1,203	1,048	1,042	1,003	999	979	938
VCT.SC.I	1,482	1,439	1,435	1,393	1,385	1,369	1,304	NA
VCS.SC.M	203	182	178	176	170	161	146	113
VCS.SC.L	607	575	565	559	544	539	532	463
VCS.SC.I	1,556	1,556	1,531	1,526	1,507	1,497	1,403	NA
SVO.RC.M	1,010	1,008	975	842	838	829	NA	NA
SVO.SC.M	2,321	2,320	2,287	2,266	2,124	2,120	2,110	NA
SOC.RC.M	702	700	693	619	617	613	606	NA
HZO.RC.M	437	431	NA	NA	NA	NA	NA	NA
HZO.RC.L	1,003	980	NA	NA	NA	NA	NA	NA
HZO.SC.M	1,338	1,337	1,330	1,322	1,302	NA	NA	NA
HZO.SC.L	2,743	2,729	NA	NA	NA	NA	NA	NA
HCT.SC.M	144	141	136	130	77	71	64	48
HCT.SC.L	272	265	255	169	166	161	150	114
HCT.SC.I	332	330	322	305	227	NA	NA	NA
HCS.SC.M	50	49	47	45	42	36	21	NA
HCS.SC.L	145	142	138	132	124	110	64	NA
PD.SC.M	444	382	307	304	301	254	238	207
SOC.SC.M	783	767	758	754	667	664	660	651

* A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.

10.2.2.2 Shipments

DOE forecasted shipments for the base case and all standards cases. These results are presented in TSD chapter 9, Shipments Analysis.

10.2.2.3 Equipment Stock

The commercial refrigeration equipment stock in a given year is the total linear footage of commercial refrigeration equipment shipped from earlier years that is still in service during that year. The NES spreadsheet model keeps track of the total linear footage of commercial refrigeration units shipped each year. For equipment with an average lifetime of 10 years, the replacement rate per year is 10 percent, and for equipment with 15-year average lifetime, the replacement rate is 6.67 percent. For units shipped in 2046, any units still remaining at the end of 2060 were assumed to be replaced.

10.2.2.4 National Annual Energy Consumption

The national AEC is the product of the annual UEC and the stocks of commercial refrigeration equipment units of each vintage for each equipment class, as shown in Eq. 10.3.

DOE initially calculated the AEC at the site (*i.e.*, electricity in kilowatt-hours consumed by the commercial refrigeration equipment units); then DOE calculated primary energy consumption from site energy consumption by applying a site-to-source conversion factor.

10.2.2.5 Site-to-Source Conversion Factor

DOE calculates primary energy savings (power plant consumption) by applying a factor to account for losses associated with the generation, transmission, and distribution of electricity. DOE derived annual average site-to-power plant factors based on the version of the National Energy Modeling System (NEMS) that corresponds to EIA's *Annual Energy Outlook 2013* (*AEO2013*).[3] The factors change over time in response to projected changes in the types of power plants projected to provide electricity to the nation. Table 10.2.6 shows the site-to-power plant factors from 2017 to the end of the projection period. For years after 2040 (the last year in the *AEO*), DOE extrapolated the trend from 2036 through 2040.

Table 10.2.6 Site-to-Source Conversion Factors*

Year	Site-to-Source Conversion Factor *Btu/kWh*		Year	Site-to-Source Conversion Factor *Btu/kWh*
2017	8,500		2039	8,771
2018	8,500		2040	8,771
2019	8,500		2041	8,665
2020	8,500		2042	8,665
2021	8,299		2043	8,665
2022	8,299		2044	8,665
2023	8,299		2045	8,665
2024	8,299		2046	8,559
2025	8,299		2047	8,559
2026	7,954		2048	8,559
2027	7,954		2049	8,559
2028	7,954		2050	8,559
2029	7,954		2051	8,559
2030	7,954		2052	8,559
2031	8,205		2053	8,559
2032	8,205		2054	8,559
2033	8,205		2055	8,559
2034	8,205		2056	8,559
2035	8,205		2057	8,559
2036	8,771		2058	8,559
2037	8,771		2059	8,559
2038	8,771		2060	8,559

10.2.2.6 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 NEMS and published in *AEO2013*. 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 10.2.7 shows the FFC energy multipliers used for commercial refrigeration equipment for selected years. The method used to calculate a time series of FFC energy multipliers is described in appendix 10D.

Table 10.2.7 Full-Fuel-Cycle Energy Multipliers (Based on *AEO2013*)

Fuel	2017	2020	2025	2030	2035	2040 to 2060
Electricity (power plant energy use)	1.042	1.041	1.040	1.040	1.041	1.040

10.3 NET PRESENT VALUE

10.3.1 Net Present Value Definition

The NPV is the value in the present of a time series of costs and savings. The NPV is given by the equation:

$$NPV = PVS - PVC$$

Eq. 10.5

Where:

PVS = present value of operating cost savings (energy, repair, and maintenance costs), and
PVC = present value of increased total installed costs (equipment purchase price and installation cost).

The PVS and PVC are determined according to the following expressions:

$$PVS = \sum_t OCS_t \times DF_t$$

Eq. 10.6

$$PVC = \sum_t TIC_t \times DF_t$$

Eq. 10.7

Where:

OCS_t = total annual operating cost savings in the year t ($),
TIC_t = total annual installed cost increases in the year t ($),
DF_t = discount factor for the year t, and
t = year (PVS is summed over 2017–2060, and PVC is summed over 2017–2046).

DOE determined the contribution to *PVC* for each year, from the compliance date of the standard (2017) through 2046, discounted to 2013. Likewise, the contribution to *PVS* was determined for each year, from the compliance date of the standard (2017) to the year when units purchased in 2017−2046 would be retired. 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.*, 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.

10.3.2 Net Present Value Inputs

Table 10.3.1 summarizes the inputs to the NPV calculation.

Table 10.3.1 Net Present Value Inputs

Input
Total Annual Installed Cost (TIC_t)
Total Annual Operating Cost Savings (OCS_t)
Discount Factor (DF_t)
Present Value of Costs (*PVC*)
Present Value of Savings (*PVS*)

10.3.2.1 Total Annual Installed Cost

The increase in the total annual installed cost for each standards case is equal to the annual change in the per-unit installed cost (difference between base case and standards case) multiplied by the shipments forecasted in the standards case. The total installed cost includes the manufacturer selling price, distribution channel markups, and installation costs. (See chapter 8 of the TSD for a discussion of the development of installed cost.) Table 10.3.2 shows the average total installed costs per linear foot for each of the equipment classes of commercial refrigeration units by efficiency level obtained from the LCC analysis (chapter 8 of the TSD).

As discussed in section 10.2.2.1, DOE first developed the market shares of efficiency levels for the base-case scenario and then used them in combination with the roll-up method (section 10.2.2.1) to estimate the market shares of efficiency levels in the standards-case scenarios. DOE used these base-case and standards-case market shares of efficiency levels in combination with the installation costs in Table 10.3.2 to calculate a weighted-average installed costs for each standards-case scenario, which are also referred to as the shipment-weighted average installation costs. These results are shown in Table 10.3.3.

Table 10.3.2 Average Installed Cost per Linear Foot by Efficiency Level

Equipment Class	Average Installed Cost per Linear Foot* *2012$/linear foot*							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	$786	$791	$803	$902	$908	$1,167	NA	NA
VOP.RC.L	$835	$841	$876	$883	$1,305	NA	NA	NA
VOP.SC.M	$1,153	$1,157	$1,162	$1,173	$1,296	$1,308	$1,573	NA
VCT.RC.M	$946	$948	$996	$1,007	$1,014	$1,016	$1,299	NA
VCT.RC.L	$1,054	$1,068	$1,080	$1,086	$1,090	$1,462	NA	NA
VCT.SC.M	$1,010	$1,021	$1,077	$1,111	$1,116	$1,128	$1,131	$1,414

Table 10.3.2 (cont)

Equipment Class	Average Installed Cost per Linear Foot* *2012$/linear foot*							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VCT.SC.L	$1,283	$1,302	$1,356	$1,360	$1,393	$1,397	$1,414	$1,795
VCT.SC.I	$1,460	$1,481	$1,484	$1,519	$1,525	$1,538	$2,066	NA
VCS.SC.M	$740	$751	$752	$753	$757	$762	$774	$1,060
VCS.SC.L	$800	$813	$816	$818	$830	$833	$839	$1,223
VCS.SC.I	$959	$959	$965	$968	$981	$987	$1,520	NA
SVO.RC.M	$694	$695	$712	$788	$793	$959	NA	NA
SVO.SC.M	$953	$954	$971	$978	$1,078	$1,090	$1,262	NA
SOC.RC.M	$1,062	$1,064	$1,066	$1,112	$1,116	$1,131	$1,254	NA
HZO.RC.M	$671	$784	NA	NA	NA	NA	NA	NA
HZO.RC.L	$741	$942	NA	NA	NA	NA	NA	NA
HZO.SC.M	$585	$586	$589	$601	$835	NA	NA	NA
HZO.SC.L	$923	$1,063	NA	NA	NA	NA	NA	NA
HCT.SC.M	$539	$540	$541	$543	$568	$572	$584	$740
HCT.SC.L	$584	$586	$589	$615	$617	$621	$632	$843
HCT.SC.I	$681	$681	$686	$699	$1,012	NA	NA	NA
HCS.SC.M	$464	$465	$466	$468	$471	$481	$593	NA
HCS.SC.L	$470	$470	$472	$473	$477	$487	$638	NA
PD.SC.M	$1,179	$1,200	$1,248	$1,251	$1,256	$1,317	$1,339	$1,739
SOC.SC.M	$1,013	$1,022	$1,026	$1,028	$1,074	$1,078	$1,092	$1,216

* A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.

Table 10.3.3 Shipment-Weighted Average Total Installed Cost per Linear Foot by Efficiency Level

Equipment Class	Shipment-Weighted Average Total Installed Cost per Linear Foot* *2012$/linear foot*							
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**
VOP.RC.M	$830	$831	$837	$908	$913	$1,167	NA	NA
VOP.RC.L	$867	$869	$887	$892	$1,305	NA	NA	NA
VOP.SC.M	$1,205	$1,206	$1,208	$1,214	$1,306	$1,317	$1,573	NA
VCT.RC.M	$990	$990	$1,008	$1,014	$1,019	$1,021	$1,299	NA
VCT.RC.L	$1,082	$1,085	$1,090	$1,093	$1,097	$1,462	NA	NA
VCT.SC.M	$1,083	$1,085	$1,104	$1,121	$1,124	$1,133	$1,135	$1,414
VCT.SC.L	$1,369	$1,371	$1,384	$1,386	$1,405	$1,407	$1,422	$1,795
VCT.SC.I	$1,508	$1,511	$1,513	$1,531	$1,535	$1,545	$2,066	NA
VCS.SC.M	$758	$759	$760	$760	$762	$766	$777	$1,060
VCS.SC.L	$824	$826	$826	$827	$834	$837	$841	$1,223
VCS.SC.I	$973	$973	$975	$977	$985	$990	$1,520	NA
SVO.RC.M	$731	$731	$740	$794	$798	$959	NA	NA
SVO.SC.M	$1,000	$1,000	$1,007	$1,011	$1,086	$1,096	$1,262	NA
SOC.RC.M	$1,097	$1,097	$1,098	$1,123	$1,126	$1,137	$1,254	NA
HZO.RC.M	$696	$784	NA	NA	NA	NA	NA	NA
HZO.RC.L	$769	$942	NA	NA	NA	NA	NA	NA
HZO.SC.M	$596	$596	$597	$607	$835	NA	NA	NA
HZO.SC.L	$962	$1,063	NA	NA	NA	NA	NA	NA
HCT.SC.M	$556	$556	$556	$557	$573	$576	$586	$740
HCT.SC.L	$610	$610	$611	$621	$622	$625	$635	$843
HCT.SC.I	$690	$690	$692	$702	$1,012	NA	NA	NA
HCS.SC.M	$471	$471	$472	$473	$475	$484	$593	NA
HCS.SC.L	$477	$477	$477	$478	$481	$489	$638	NA
PD.SC.M	$1,253	$1,256	$1,271	$1,273	$1,276	$1,323	$1,343	$1,739
SOC.SC.M	$1,052	$1,053	$1,055	$1,056	$1,083	$1,086	$1,098	$1,216

* A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.

10.3.2.2 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 CRE manufacturing process over time, DOE used a price forecast methodology based on experiential learning (see appendixes 8D and 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.

Table 10.3.4 summarizes four learning scenarios that DOE developed. 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 CRE shipments and Producer Price Index data. Appendix 10B of this TSD documents the development of the price learning scenarios. For this notice, DOE used the historically derived reference scenario for the results presented in this chapter and in the NOPR.

Table 10.3.4 Price Trend Scenarios

Year	Constant Prices	Historically Derived Price Trends		
		High	Reference	Low
2012	100.00%	100.00%	100.00%	100.00%
2013	100.00%	100.03%	99.89%	99.75%
2014	100.00%	100.06%	99.78%	99.50%
2015	100.00%	100.10%	99.67%	99.25%
2016	100.00%	100.13%	99.56%	99.00%
2017	100.00%	100.16%	99.45%	98.75%
2018	100.00%	100.19%	99.34%	98.50%
2019	100.00%	100.23%	99.23%	98.24%
2020	100.00%	100.26%	99.12%	98.00%
2021	100.00%	100.29%	99.02%	97.77%
2022	100.00%	100.32%	98.92%	97.54%
2023	100.00%	100.35%	98.82%	97.32%
2024	100.00%	100.38%	98.72%	97.10%
2025	100.00%	100.41%	98.62%	96.87%
2026	100.00%	100.44%	98.52%	96.65%
2027	100.00%	100.47%	98.43%	96.43%
2028	100.00%	100.50%	98.33%	96.20%
2029	100.00%	100.53%	98.23%	95.98%
2030	100.00%	100.55%	98.13%	95.76%
2031	100.00%	100.58%	98.03%	95.55%
2032	100.00%	100.61%	97.94%	95.34%
2033	100.00%	100.64%	97.85%	95.13%
2034	100.00%	100.67%	97.76%	94.93%
2035	100.00%	100.69%	97.66%	94.73%
2036	100.00%	100.72%	97.57%	94.52%
2037	100.00%	100.75%	97.48%	94.32%
2038	100.00%	100.78%	97.39%	94.11%
2039	100.00%	100.80%	97.30%	93.91%
2040	100.00%	100.83%	97.21%	93.71%
2041	100.00%	100.86%	97.12%	93.52%
2042	100.00%	100.89%	97.03%	93.32%
2043	100.00%	100.91%	96.94%	93.13%
2044	100.00%	100.94%	96.86%	92.94%
2045	100.00%	100.97%	96.77%	92.75%
2046	100.00%	100.99%	96.68%	92.56%

10.3.2.3 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 applicable equipment and CSL combination. Table 10.3.5 shows the normalized LED price deflators used to reduce the price of the LED design option where applicable. For the period of 2017 through 2030, the cost of equipment with LED lighting included was reduced by an amount corresponding to a reduction in LED prices following the deflators shown on Table 10.3.5.

Table 10.3.5 LED price deflators used in the NOPR analysis.

Year	Normalized to 2013	Normalized to 2017		Year	Normalized to 2013	Normalized to 2017
2010	2.998	5.652		**2021**	0.361	0.681
2011	1.799	3.392		**2022**	0.335	0.631
2012	1.285	2.423		**2023**	0.312	0.588
2013	1.000	1.885		**2024**	0.292	0.550
2014	0.819	1.543		**2025**	0.274	0.517
2015	0.693	1.306		**2026**	0.259	0.488
2016	0.601	1.133		**2027**	0.245	0.462
2017	0.530	1.000		**2028**	0.232	0.438
2018	0.475	0.895		**2029**	0.221	0.417
2019	0.430	0.810		**2030**	0.211	0.398
2020	0.393	0.740		**2031-2046***	0.211	0.398

* DOE did not have data available to project prices beyond 2030. Therefore, for the NOPR analysis, it was assumed that the LED prices stay constant after 2030.

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.

10.3.2.4 Total Annual Operating Cost Savings

The annual operating cost savings to the nation are equal to the change in the annual operating costs (difference between base case and standards case) per unit multiplied by the shipments forecasted in the standards case. The annual operating cost includes energy, repair, and maintenance costs.

Annual Electricity Cost Savings. As described in TSD chapter 8, Life-Cycle Cost and Payback Period Analysis, DOE calculated annual electricity costs based on average state-level commercial electricity prices. To calculate annual energy cost savings for a particular equipment class in a given year, DOE first calculated the annual energy costs in each forecast year at the base-case scenario and each standards-case scenario by multiplying the weighted-average energy consumption at each efficiency level from Table 10.2.5 by the linear feet of equipment stock in the equipment class in each year, and then by the sales-weighted national average electricity prices for the seven building types in TSD chapter 8. To determine energy savings at each standards-case scenario, the national energy costs at each standards-case scenario were then subtracted from the national energy costs at the base-case scenario. Because projections of the stock of commercial refrigeration equipment (expressed in linear feet) are the primary driver used to estimate future commercial refrigeration equipment shipments, DOE calculated the national energy cost by expressing the AEC on a linear-footage basis.

Annual Repair Costs. DOE based average annual repair costs on the value of the components of the equipment at each efficiency level (see TSD chapter 8). Table 10.3.6 shows the average repair costs per linear foot for each efficiency level for the equipment classes analyzed. Table 10.3.7 presents the shipment-weighted average annual repair costs per linear foot for the base-case and all standards-case scenarios for each equipment class.

Table 10.3.6 Average Annual Repair Cost per Linear Foot by Efficiency Level

Equipment Class	Average Annual Repair Cost per Linear Foot* *2012$/linear foot*							
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**
VOP.RC.M	$32.29	$32.29	$32.41	$32.41	$32.41	$32.41	NA	NA
VOP.RC.L	$37.52	$37.58	$37.58	$37.58	$37.58	NA	NA	NA
VOP.SC.M	$56.58	$56.58	$56.85	$57.43	$57.43	$57.43	$57.43	NA
VCT.RC.M	$42.09	$42.29	$42.79	$42.79	$42.79	$42.81	$42.81	NA
VCT.RC.L	$48.59	$48.74	$48.74	$48.74	$48.78	$48.78	NA	NA
VCT.SC.M	$47.40	$48.20	$48.95	$48.95	$49.24	$49.24	$49.26	$49.26
VCT.SC.L	$63.80	$64.19	$65.54	$65.59	$65.59	$65.77	$66.06	$66.06
VCT.SC.I	$75.54	$75.76	$75.95	$75.95	$76.25	$76.25	$76.25	NA
VCS.SC.M	$30.24	$31.20	$31.28	$31.29	$31.47	$31.76	$31.76	$31.76
VCS.SC.L	$35.28	$36.31	$36.49	$36.51	$36.51	$36.69	$36.98	$36.98
VCS.SC.I	$46.32	$46.34	$46.62	$46.81	$46.81	$47.12	$47.12	NA
SVO.RC.M	$26.94	$26.95	$26.95	$26.95	$26.95	$26.95	NA	NA
SVO.SC.M	$43.87	$43.87	$43.87	$44.26	$44.26	$44.26	$44.26	NA
SOC.RC.M	$45.62	$45.78	$45.81	$45.81	$45.81	$45.96	$45.96	NA
HZO.RC.M	$25.59	$25.59	NA	NA	NA	NA	NA	NA
HZO.RC.L	$29.15	$29.15	NA	NA	NA	NA	NA	NA
HZO.SC.M	$23.54	$23.56	$23.73	$23.73	$23.73	NA	NA	NA
HZO.SC.L	$44.57	$44.57	NA	NA	NA	NA	NA	NA
HCT.SC.M	$17.81	$17.82	$17.90	$17.99	$18.26	$18.46	$18.46	$18.46
HCT.SC.L	$21.77	$21.79	$21.95	$22.22	$22.32	$22.52	$22.52	$22.52
HCT.SC.I	$26.28	$26.29	$26.52	$26.52	$26.52	NA	NA	NA
HCS.SC.M	$14.65	$14.66	$14.73	$14.81	$15.00	$15.00	$15.00	NA
HCS.SC.L	$14.90	$14.90	$14.97	$15.06	$15.24	$15.24	$15.24	NA
PD.SC.M	$49.34	$50.43	$50.94	$51.10	$51.36	$51.36	$51.39	$51.39
SOC.SC.M	$50.42	$51.05	$51.14	$51.25	$51.25	$51.25	$51.40	$51.40

* A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.

Table 10.3.7 Shipment-Weighted Average Annual Repair Cost per Linear Foot by Efficiency Level

Equipment Class	Shipment-Weighted Average Annual Repair Cost per Linear Foot* *2012$/linear foot*							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	$32.35	$32.35	$32.41	$32.41	$32.41	$32.41	NA	NA
VOP.RC.L	$37.56	$37.58	$37.58	$37.58	$37.58	NA	NA	NA
VOP.SC.M	$57.00	$57.00	$57.10	$57.43	$57.43	$57.43	$57.43	NA
VCT.RC.M	$42.57	$42.60	$42.79	$42.79	$42.79	$42.81	$42.81	NA
VCT.RC.L	$48.72	$48.75	$48.75	$48.75	$48.78	$48.78	NA	NA
VCT.SC.M	$48.67	$48.81	$49.06	$49.06	$49.24	$49.24	$49.26	$49.26
VCT.SC.L	$65.30	$65.34	$65.67	$65.69	$65.69	$65.81	$66.06	$66.06
VCT.SC.I	$75.94	$75.98	$76.05	$76.05	$76.25	$76.25	$76.25	NA
VCS.SC.M	$31.30	$31.42	$31.44	$31.45	$31.55	$31.76	$31.76	$31.76
VCS.SC.L	$36.42	$36.54	$36.59	$36.60	$36.60	$36.73	$36.98	$36.98
VCS.SC.I	$46.67	$46.67	$46.76	$46.86	$46.86	$47.12	$47.12	NA
SVO.RC.M	$26.95	$26.95	$26.95	$26.95	$26.95	$26.95	NA	NA
SVO.SC.M	$44.03	$44.04	$44.04	$44.26	$44.26	$44.26	$44.26	NA
SOC.RC.M	$45.79	$45.82	$45.83	$45.83	$45.83	$45.96	$45.96	NA
HZO.RC.M	$25.59	$25.59	NA	NA	NA	NA	NA	NA
HZO.RC.L	$29.15	$29.15	NA	NA	NA	NA	NA	NA
HZO.SC.M	$23.64	$23.65	$23.73	$23.73	$23.73	NA	NA	NA
HZO.SC.L	$44.57	$44.57	NA	NA	NA	NA	NA	NA
HCT.SC.M	$18.08	$18.08	$18.10	$18.15	$18.31	$18.46	$18.46	$18.46
HCT.SC.L	$22.18	$22.18	$22.22	$22.33	$22.38	$22.52	$22.52	$22.52
HCT.SC.I	$26.40	$26.40	$26.52	$26.52	$26.52	NA	NA	NA
HCS.SC.M	$14.80	$14.80	$14.83	$14.87	$15.00	$15.00	$15.00	NA
HCS.SC.L	$15.05	$15.05	$15.07	$15.12	$15.24	$15.24	$15.24	NA
PD.SC.M	$50.81	$50.97	$51.12	$51.20	$51.37	$51.37	$51.39	$51.39
SOC.SC.M	$51.11	$51.20	$51.23	$51.28	$51.28	$51.28	$51.40	$51.40

* A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.

Annual Maintenance Costs. DOE determined average annual maintenance costs in two parts. The first was a preventative maintenance cost of $35/year for self-contained units and $220/year for remote condensing units (see TSD chapter 8). The second was a lighting maintenance cost for equipment classes that feature lights within the equipment. The lighting cost varied with efficiency level because the costs were directly proportional to the original equipment manufacturer costs of the lighting (see TSD chapter 8). Table 10.3.8 shows the resulting annual maintenance costs per linear foot by efficiency level. Table 10.3.9 shows the corresponding shipments-weighted annual maintenance cost per linear foot by efficiency level.

Table 10.3.8 Average Annual Maintenance Cost per Linear Foot by Efficiency Level

Equipment Class	Average Annual Maintenance Cost per Linear Foot* *2012$/linear foot*							
	Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**
VOP.RC.M	$26.65	$26.65	$26.65	$28.54	$28.54	$28.54	NA	NA
VOP.RC.L	$22.08	$22.08	$21.65	$21.65	$21.65	NA	NA	NA
VOP.SC.M	$22.66	$22.66	$22.66	$22.66	$24.90	$24.90	$24.90	NA
VCT.RC.M	$20.14	$20.14	$20.14	$20.14	$20.14	$20.14	$20.14	NA
VCT.RC.L	$20.11	$20.11	$20.11	$20.11	$20.11	$20.11	NA	NA
VCT.SC.M	$13.22	$13.22	$13.22	$13.22	$13.22	$13.22	$13.22	$13.22
VCT.SC.L	$17.45	$13.22	$13.22	$13.22	$13.22	$13.22	$13.22	$13.22
VCT.SC.I	$13.83	$13.83	$13.83	$13.83	$13.83	$13.83	$13.83	NA
VCS.SC.M	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92
VCS.SC.L	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92
VCS.SC.I	$8.28	$8.28	$8.28	$8.28	$8.28	$8.28	$8.28	NA
SVO.RC.M	$24.36	$24.36	$24.36	$26.36	$26.36	$26.36	NA	NA
SVO.SC.M	$18.53	$18.53	$18.53	$18.53	$21.34	$21.34	$21.34	NA
SOC.RC.M	$24.36	$24.36	$24.36	$24.63	$24.63	$24.63	$24.63	NA
HZO.RC.M	$18.66	$18.66	NA	NA	NA	NA	NA	NA
HZO.RC.L	$18.66	$18.66	NA	NA	NA	NA	NA	NA
HZO.SC.M	$8.91	$8.91	$8.91	$8.91	$8.91	NA	NA	NA
HZO.SC.L	$8.91	$8.91	NA	NA	NA	NA	NA	NA
HCT.SC.M	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37
HCT.SC.L	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37
HCT.SC.I	$10.42	$10.42	$10.42	$10.42	$10.42	NA	NA	NA
HCS.SC.M	$8.48	$8.48	$8.48	$8.48	$8.48	$8.48	$8.48	NA
HCS.SC.L	$8.48	$8.48	$8.48	$8.48	$8.48	$8.48	$8.48	NA
PD.SC.M	$19.34	$20.03	$20.03	$20.03	$20.03	$20.03	$20.03	$20.03
SOC.SC.M	$10.73	$12.12	$12.12	$12.12	$12.61	$12.61	$12.61	$12.61

* A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.

Table 10.3.9 Shipment-Weighted Average Annual Maintenance Cost per Linear Foot by Efficiency Level

Equipment Class	Shipment-Weighted Average Annual Maintenance Cost per Linear Foot* *2012$/linear foot*							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	$27.18	$27.18	$27.18	$28.54	$28.54	$28.54	NA	NA
VOP.RC.L	$21.87	$21.87	$21.65	$21.65	$21.65	NA	NA	NA
VOP.SC.M	$23.22	$23.22	$23.22	$23.22	$24.90	$24.90	$24.90	NA
VCT.RC.M	$20.14	$20.14	$20.14	$20.14	$20.14	$20.14	$20.14	NA
VCT.RC.L	$20.11	$20.11	$20.11	$20.11	$20.11	$20.11	NA	NA
VCT.SC.M	$13.22	$13.22	$13.22	$13.22	$13.22	$13.22	$13.22	$13.22
VCT.SC.L	$13.66	$13.22	$13.22	$13.22	$13.22	$13.22	$13.22	$13.22
VCT.SC.I	$13.83	$13.83	$13.83	$13.83	$13.83	$13.83	$13.83	NA
VCS.SC.M	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92
VCS.SC.L	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92	$7.92
VCS.SC.I	$8.28	$8.28	$8.28	$8.28	$8.28	$8.28	$8.28	NA
SVO.RC.M	$24.94	$24.94	$24.94	$26.36	$26.36	$26.36	NA	NA
SVO.SC.M	$19.22	$19.22	$19.22	$19.22	$21.34	$21.34	$21.34	NA
SOC.RC.M	$24.49	$24.49	$24.49	$24.63	$24.63	$24.63	$24.63	NA
HZO.RC.M	$18.66	$18.66	NA	NA	NA	NA	NA	NA
HZO.RC.L	$18.66	$18.66	NA	NA	NA	NA	NA	NA
HZO.SC.M	$8.91	$8.91	$8.91	$8.91	$8.91	NA	NA	NA
HZO.SC.L	$8.91	$8.91	NA	NA	NA	NA	NA	NA
HCT.SC.M	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37
HCT.SC.L	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37
HCT.SC.I	$10.42	$10.42	$10.42	$10.42	$10.42	NA	NA	NA
HCS.SC.M	$8.48	$8.48	$8.48	$8.48	$8.48	$8.48	$8.48	NA
HCS.SC.L	$8.48	$8.48	$8.48	$8.48	$8.48	$8.48	$8.48	NA
PD.SC.M	$19.93	$20.03	$20.03	$20.03	$20.03	$20.03	$20.03	$20.03
SOC.SC.M	$12.12	$12.32	$12.32	$12.32	$12.61	$12.61	$12.61	$12.61

* A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.

10.3.2.5 Discount Factor

DOE multiplied monetary values in future years by the discount factor in order to determine the present value of costs and savings. The discount factor (*DF*) is described by the equation:

$$DF = \frac{1}{(1+r)^{(t-t_p)}}$$

Eq. 10.8

Where:

r = discount rate,
t = year of the monetary value, and
t_p = year in which the present value is being determined.

DOE estimated national impacts with both a 3-percent and a 7-percent real discount rate as the average real rate of return on private investment in the U.S. economy. These discount rates are used in accordance with the Office of Management and Budget (OMB) guidance to Federal agencies on the development of regulatory analysis (OMB Circular A-4, September 17, 2003), and section E, "Identifying and Measuring Benefits and Costs," therein. DOE defined the present year as 2013 for the NOPR.

10.3.2.6 Present Value of Costs

The present value of increased installed costs is the annual installed cost increase in each year (*i.e.*, the difference between the standards case and base case) discounted to the present year and summed for the time period over which DOE is considering the installation of commercial refrigeration equipment (*i.e.*, from the compliance date of standards, 2017, through the year 2046).

The increase in total installed cost refers to both equipment cost and installation cost associated with the higher energy efficiency of commercial refrigeration units purchased in the standards case compared to the base case. DOE calculated annual installed costs as the difference in total installed cost for new equipment purchased each year, multiplied by the shipments in the standards case.

10.3.2.7 Present Value of Savings

The present value of the operating cost savings is the annual operating cost savings (*i.e.*, the difference between the base case and standards case) discounted to the present year, and summed over the period from the compliance date of the standard, 2017, to the time when the last unit installed in 2017−2046 is retired from service. Savings are decreases in operating costs (including electricity, repair, and maintenance) associated with the higher energy efficiency of commercial refrigeration units purchased in the standards case compared to the base case. Total annual operating cost savings are the savings per unit multiplied by the number of units of each vintage surviving in a particular year. Equipment consumes energy over its entire lifetime, and for units purchased in 2046, the present value of savings includes energy consumed until the unit is retired from service at the end of 2060.

10.4 NATIONAL ENERGY SAVINGS AND NET PRESENT VALUE RESULTS

The NES spreadsheet model provides estimates of the NES and NPV due to various efficiency levels. The inputs to the NES spreadsheet are discussed in sections 10.2.2 and 10.3.2. DOE generated the NES and NPV results using a Microsoft Excel spreadsheet, which is available at http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/52. Details and instructions for using the spreadsheet are provided in appendix 10A.

For this NOPR analysis, DOE selected five trial standard level (TSL) groupings based on the NPV values calculated for each CSL. Appendix 10C discusses the criteria used for selection of TSLs. The NIA results in this section are presented for CSLs and TSLs.

10.4.1 National Energy Savings and Net Present Value Input Summary

Table 10.4.1 summarizes the inputs to the NES spreadsheet model. For each input, a brief description of the data source is given.

Table 10.4.1 NES and NPV Inputs

Input Data	Description
Shipments	Annual shipments from shipments model (see TSD chapter 9, Shipments Analysis).
Effective Date of Standard	2017
Base-Case Efficiencies	Distribution of base-case shipments by efficiency level.
Standards-Case Efficiencies	Distribution of shipments by efficiency level for each standards case. Standards-case annual market shares by efficiency level remain constant over time for the base case and each standards case.
Annual Energy Consumption per Linear Foot	Annual weighted-average values are a function of efficiency level (established in the engineering analysis, TSD chapter 5) converted to a per-linear-foot basis.
Total Installed Cost per Linear Foot	Annual weighted-average values of installed cost are a function of efficiency level (see TSD chapter 8), expressed on a per-linear-foot basis.
Repair Cost per Linear Foot	Annual weighted-average values of repair costs are constant with efficiency level (see TSD chapter 8). Converted to a per-linear-foot basis.
Maintenance Cost per Linear Foot	Annual weighted-average value equals $35 for self-contained and $220 for remote condensing units (see TSD chapter 8), plus lighting maintenance cost. Converted to a per-linear-foot basis.
Escalation of Electricity Prices	EIA *AEO2013* forecasts (to 2040) and extrapolation for 2040 and beyond (see TSD chapter 8).
Electricity Site-to-Source Conversion	Conversion varies yearly and is generated by DOE's version of the EIA NEMS program (a time series conversion factor; includes electric generation, transmission, and distribution losses).
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).
Discount Rate	3- and 7-percent real
Present Year	Future costs are discounted to year 2013.

10.4.2 National Energy Savings Results

This section provides NES results for each energy consumption level considered for the 25 equipment classes of commercial refrigeration equipment DOE directly analyzed. Results are cumulative to 2060 and are shown as primary energy savings in quads. Inputs to the NES spreadsheet model are based on weighted-average values, yielding results that are discrete point values, rather than a distribution of values as in the LCC analysis.

Table 10.4.2 shows the NES results, without FFC, for all CSLs for all equipment classes. Table 10.4.3 shows the NES results, without FFC, by TSLs. Table 10.4.4 shows the NES results, with FFC, for all CSLs for all equipment classes. Table 10.4.5 shows the NES results, with FFC, by TSLs. Table 10.4.6 presents the NES values with FFC at the five TSLs expressed as a percentage of total base-case energy usage of the equipment stock in the period 2017–2060.

Table 10.4.2 Cumulative National Energy Savings, without Full-Fuel-Cycle, by CSL for Equipment Purchased in 2017–2046

Equipment Class	National Energy Savings by CSL*,** *quads*						
	Level 2	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**
VOP.RC.M	0.007	0.045	0.238	0.244	0.257	NA	NA
VOP.RC.L	0.001	0.005	0.006	0.009	NA	NA	NA
VOP.SC.M	0.000	0.001	0.003	0.017	0.018	0.019	NA
VCT.RC.M	0.000	0.007	0.009	0.009	0.009	0.010	NA
VCT.RC.L	0.034	0.061	0.071	0.078	0.121	NA	NA
VCT.SC.M	0.011	0.057	0.074	0.077	0.081	0.081	0.092
VCT.SC.L	0.002	0.005	0.005	0.006	0.006	0.007	0.008
VCT.SC.I	0.001	0.001	0.002	0.003	0.003	0.005	NA
VCS.SC.M	0.040	0.047	0.052	0.064	0.082	0.111	0.176
VCS.SC.L	0.032	0.042	0.048	0.064	0.068	0.076	0.144
VCS.SC.I	0.000	0.000	0.000	0.000	0.000	0.001	NA
SVO.RC.M	0.002	0.029	0.139	0.142	0.150	NA	NA
SVO.SC.M	0.000	0.004	0.006	0.021	0.022	0.023	NA
SOC.RC.M	0.001	0.002	0.017	0.018	0.019	0.020	NA
HZO.RC.M	0.001	NA	NA	NA	NA	NA	NA
HZO.RC.L	0.009	NA	NA	NA	NA	NA	NA
HZO.SC.M	0.000	0.000	0.000	0.000	NA	NA	NA
HZO.SC.L	0.000	NA	NA	NA	NA	NA	NA
HCT.SC.M	0.000	0.000	0.000	0.000	0.000	0.000	0.001
HCT.SC.L	0.000	0.001	0.004	0.004	0.004	0.005	0.006
HCT.SC.I	0.000	0.000	0.001	0.005	NA	NA	NA
HCS.SC.M	0.001	0.001	0.002	0.004	0.006	0.013	NA
HCS.SC.L	0.000	0.000	0.001	0.001	0.002	0.005	NA
PD.SC.M	0.047	0.105	0.106	0.109	0.145	0.157	0.181
SOC.SC.M	0.000	0.000	0.000	0.002	0.002	0.002	0.002

* A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.
** 0.000 indicates savings are less than 0.0005 quads.

Table 10.4.3 Cumulative National Energy Savings, without Full-Fuel-Cycle, by TSL for Equipment Purchased in 2017–2046

Equipment Class	National Energy Savings by TSL* *quads*				
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	0.007	0.045	0.238	0.244	0.257
VOP.RC.L	0.001	0.005	0.006	0.006	0.009
VOP.SC.M	0.001	0.003	0.017	0.018	0.019
VCT.RC.M	0.000	0.007	0.009	0.009	0.010
VCT.RC.L	0.061	0.071	0.078	0.078	0.121
VCT.SC.M	0.011	0.057	0.074	0.081	0.092
VCT.SC.L	0.005	0.005	0.006	0.007	0.008
VCT.SC.I	0.001	0.003	0.003	0.003	0.005
VCS.SC.M	0.047	0.064	0.111	0.111	0.176
VCS.SC.L	0.042	0.064	0.068	0.076	0.144
VCS.SC.I	0.000	0.000	0.000	0.000	0.001
SVO.RC.M	0.002	0.029	0.139	0.142	0.150
SVO.SC.M	0.004	0.006	0.021	0.022	0.023
SOC.RC.M	0.001	0.002	0.017	0.019	0.020
HZO.RC.M	–	–	–	–	0.001
HZO.RC.L	–	–	–	–	0.009
HZO.SC.M	0.000	0.000	0.000	0.000	0.000
HZO.SC.L	–	–	–	–	0.000
HCT.SC.M	0.000	0.000	0.000	0.000	0.001
HCT.SC.L	0.001	0.004	0.004	0.005	0.006
HCT.SC.I	0.000	0.000	0.001	0.001	0.005
HCS.SC.M	0.001	0.001	0.002	0.004	0.013
HCS.SC.L	0.001	0.001	0.002	0.002	0.005
PD.SC.M	0.047	0.047	0.105	0.157	0.181
SOC.SC.M	0.000	0.000	0.002	0.002	0.002
Net NES	0.233	0.416	0.905	0.985	1.257

"–" represents zero energy savings, since TSLs 1 through 4 for the equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level.
*A value of 0.000 means NES values are less than 0.0005 quads.

Table 10.4.4 Cumulative National Energy Savings, with Full-Fuel-Cycle, by CSL for Equipment purchased in 2017–2046

Equipment Class	National Energy Savings (quads) by Standard Level*						
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	0.007	0.046	0.242	0.248	0.262	NA	NA
VOP.RC.L	0.001	0.005	0.006	0.009	NA	NA	NA
VOP.SC.M	0.000	0.001	0.003	0.018	0.018	0.019	NA
VCT.RC.M	0.000	0.007	0.009	0.009	0.009	0.010	NA
VCT.RC.L	0.035	0.062	0.072	0.079	0.123	NA	NA
VCT.SC.M	0.011	0.058	0.075	0.078	0.082	0.083	0.094
VCT.SC.L	0.002	0.005	0.006	0.006	0.007	0.007	0.008
VCT.SC.I	0.001	0.001	0.002	0.003	0.003	0.005	NA
VCS.SC.M	0.041	0.048	0.053	0.065	0.083	0.112	0.179
VCS.SC.L	0.033	0.043	0.049	0.065	0.070	0.077	0.146
VCS.SC.I	0.000	0.000	0.000	0.000	0.000	0.001	NA
SVO.RC.M	0.002	0.030	0.141	0.144	0.152	NA	NA
SVO.SC.M	0.000	0.004	0.006	0.022	0.022	0.023	NA
SOC.RC.M	0.001	0.002	0.018	0.018	0.019	0.020	NA

Table 10.4.4 (cont)

Equipment Class	National Energy Savings (quads) by Standard Level*						
	Level 2	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**
HZO.RC.M	0.001	NA	NA	NA	NA	NA	NA
HZO.RC.L	0.009	NA	NA	NA	NA	NA	NA
HZO.SC.M	0.000	0.000	0.000	0.000	NA	NA	NA
HZO.SC.L	0.000	NA	NA	NA	NA	NA	NA
HCT.SC.M	0.000	0.000	0.000	0.000	0.000	0.000	0.001
HCT.SC.L	0.000	0.001	0.004	0.004	0.004	0.005	0.006
HCT.SC.I	0.000	0.000	0.001	0.005	NA	NA	NA
HCS.SC.M	0.001	0.001	0.002	0.004	0.006	0.013	NA
HCS.SC.L	0.000	0.000	0.001	0.001	0.002	0.005	NA
PD.SC.M	0.048	0.106	0.108	0.111	0.147	0.159	0.184
SOC.SC.M	0.000	0.000	0.000	0.002	0.002	0.002	0.002

*A value of 0.000 means NES values are less than 0.0005 quads.

Table 10.4.5 Cumulative Energy Savings, with Full-Fuel-Cycle, by TSL for Equipment Purchased in 2017–2046

Equipment Class	Standard Level*				
	TSL1	TSL2	TSL3	TSL4	TSL5
VOP.RC.M	0.007	0.046	0.242	0.248	0.262
VOP.RC.L	0.001	0.005	0.006	0.006	0.009
VOP.SC.M	0.001	0.003	0.018	0.018	0.019
VCT.RC.M	0.000	0.007	0.009	0.009	0.010
VCT.RC.L	0.062	0.072	0.079	0.079	0.123
VCT.SC.M	0.011	0.058	0.075	0.083	0.094
VCT.SC.L	0.005	0.006	0.007	0.007	0.008
VCT.SC.I	0.001	0.003	0.003	0.003	0.005
VCS.SC.M	0.048	0.065	0.112	0.112	0.179
VCS.SC.L	0.043	0.065	0.070	0.077	0.146
VCS.SC.I	0.000	0.000	0.000	0.000	0.001
SVO.RC.M	0.002	0.030	0.141	0.144	0.152
SVO.SC.M	0.004	0.006	0.022	0.022	0.023
SOC.RC.M	0.001	0.002	0.018	0.019	0.020
HZO.RC.M	–	–	–	–	0.001
HZO.RC.L	–	–	–	–	0.009
HZO.SC.M	0.000	0.000	0.000	0.000	0.000
HZO.SC.L	–	–	–	–	0.000
HCT.SC.M	0.000	0.000	0.000	0.000	0.001
HCT.SC.L	0.001	0.004	0.004	0.005	0.006
HCT.SC.I	0.000	0.000	0.001	0.001	0.005
HCS.SC.M	0.001	0.001	0.002	0.004	0.013
HCS.SC.L	0.001	0.001	0.002	0.002	0.005
PD.SC.M	0.048	0.048	0.106	0.159	0.184
SOC.SC.M	0.000	0.000	0.002	0.002	0.002
Total	0.236	0.422	0.920	1.001	1.278

"–" represents zero energy savings, since TSLs 1 through 4 for the equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level.
*A value of 0.000 means NES values are less than 0.0005 quads.

Table 10.4.6 Cumulative Energy Savings, with Full-Fuel-Cycle, by TSL Expressed as a Percentage of Cumulative Base-Case Energy Usage of the Total Equipment Stock

Equipment Class	Total Base-Case Energy Use 2017-2060* *quads*	TSL Savings as Percent of Total Base-Case Energy Use				
		TSL 1	TSL 2	TSL 3	TSL 4	TSL5
VOP.RC.M	1.606	0	3	15	15	16
VOP.RC.L	0.203	0	3	3	3	4
VOP.SC.M	0.231	1	1	8	8	8
VCT.RC.M	0.027	1	25	33	35	39
VCT.RC.L	1.198	5	6	7	7	10
VCT.SC.M	0.235	5	25	32	35	40
VCT.SC.L	0.036	15	15	18	19	22
VCT.SC.I	0.047	3	6	7	7	10
VCS.SC.M	0.472	10	14	24	24	38
VCS.SC.L	0.720	6	9	10	11	20
VCS.SC.I	0.012	1	3	3	3	8
SVO.RC.M	0.990	0	3	14	15	15
SVO.SC.M	0.300	1	2	7	7	8
SOC.RC.M	0.173	0	1	10	11	12
HZO.RC.M	0.066	0	0	0	0	1
HZO.RC.L	0.475	0	0	0	0	2
HZO.SC.M	0.015	0	0	1	1	2
HZO.SC.L	0.063	0	0	0	0	0
HCT.SC.M	0.001	5	40	43	48	57
HCT.SC.L	0.012	6	33	33	38	50
HCT.SC.I	0.017	1	3	7	7	27
HCS.SC.M	0.026	2	5	8	14	49
HCS.SC.L	0.010	8	13	21	21	48
PD.SC.M	0.401	12	12	27	40	46
SOC.SC.M	0.014	3	3	13	13	14
Totals	7.349	3	6	13	14	17

* Stock energy usage with base-case efficiency distribution across efficiency levels.

10.4.3 Annual Costs and Savings

This section presents the annual equipment cost increases and annual operating cost savings at the national level. Figure 10.4.1 shows the changes over time of the non-discounted annual equipment price increases and the non-discounted operating cost savings at Level 4 for the VOP.RC.M equipment class. The total net annual impact is the discounted value of the difference between annual equipment purchases and annual operating costs at a 7-percent discount rate. The NIA model can produce similar figures for all efficiency levels for all equipment classes. On the figure, net annual impact is the difference between the savings and costs for each year with appropriate discounting. The annual equipment price change is the increase in equipment price for equipment purchased each year over the period 2017–2046. The annual operating savings is the savings in operating costs for equipment purchased, and which has not been retired, for each year over the time period 2017–2060.

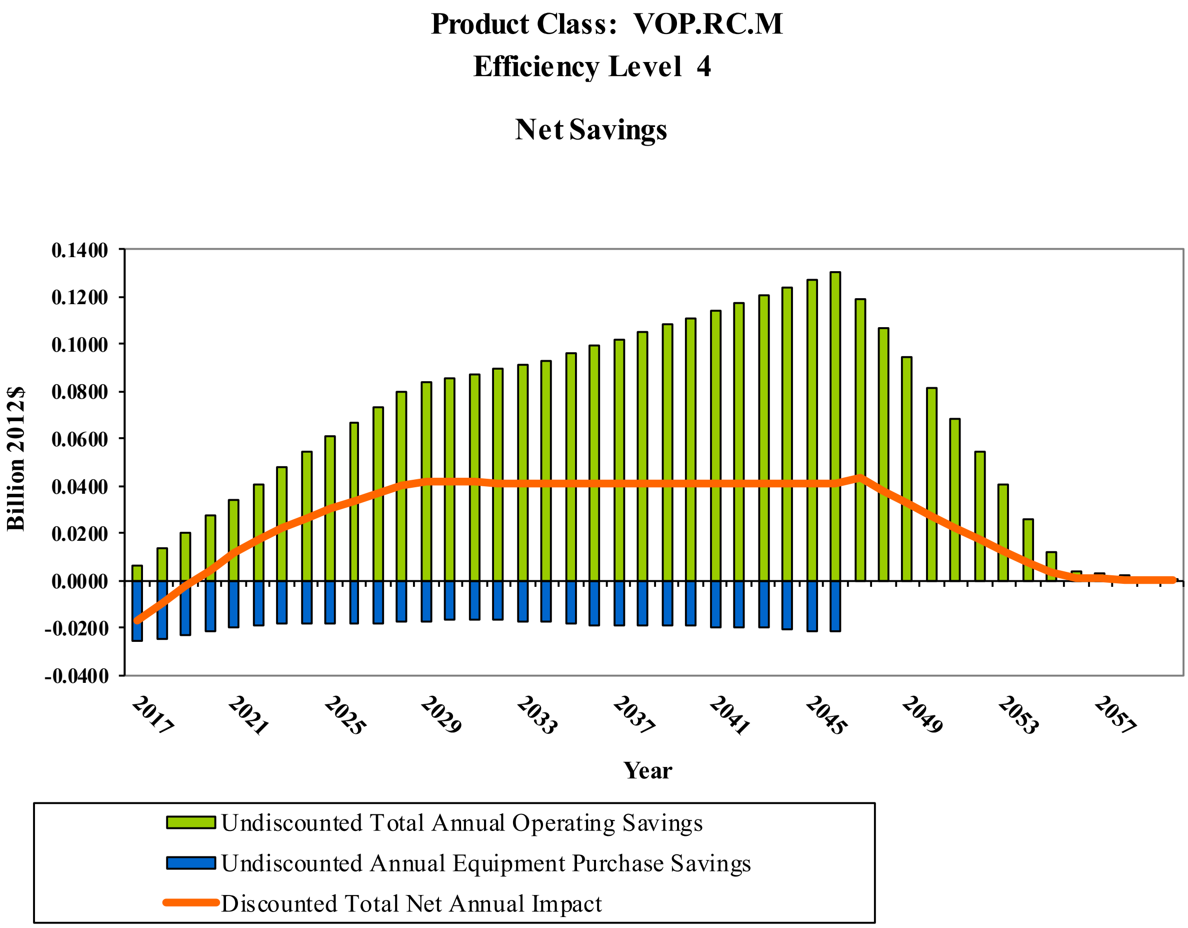

Figure 10.4.1 National Annual Costs and Savings for Efficiency Level 4 for Equipment Class VOP.RC.M

Figure 10.4.1 initially shows smaller annual operating cost savings compared to the increased equipment price costs (shown on the figure as operating savings). Operating cost savings increase with time, as more and more equipment meeting the efficiency level replaces less efficient equipment in the commercial refrigeration equipment stock.

10.4.4 Net Present Value Results

This section provides NPV results for the CSLs considered for the selected equipment classes of commercial refrigeration units. Results are cumulative and are shown as the discounted values of these savings in dollar terms. The inputs to the NES spreadsheet model are based on weighted-average values, yielding results that are discrete point values rather than a distribution of values as in the LCC analysis. The present value of increased total installed costs is the total installed cost increase (*i.e.*, the difference between the standards case and base case) discounted to 2013 and summed over the time period in which DOE evaluates the impact of standards.

Savings are decreases in operating costs (including electricity, repair, and maintenance) associated with the higher energy efficiency of commercial refrigeration units purchased in the standards case compared to the base case. Total operating cost savings are the savings per unit multiplied by the number of units of each vintage (*i.e.*, the year of manufacture) that remain in operation in a particular year. Commercial refrigeration equipment consumes energy and must be maintained over its entire lifetime. The operating cost includes energy consumed and maintenance and repair costs incurred until all units purchased in the analysis period 2017–2046 are retired from service (2060).

Table 10.4.7 shows the NPV results for the CSLs considered for commercial refrigeration equipment based on a 7-percent discount rate. DOE based all results on electricity price forecasts from the *AEO2013* Reference Case. Table 10.4.8 presents the NPV results by TSL for the 7-percent discount rate.

Table 10.4.7 Cumulative NPV Results by CSL Based on a 7-Percent Discount Rate (billion 2012$)

Equipment Class	*billion 2012$**,**,†						
	Level 2	**Level 3**	**Level 4**	**Level 5**	**Level 6**	**Level 7**	**Level 8**
VOP.RC.M	0.016	0.099	0.466	0.461	(0.466)	NA	NA
VOP.RC.L	0.002	0.013	0.014	(0.062)	NA	NA	NA
VOP.SC.M	0.001	0.003	0.005	0.027	0.025	(0.041)	NA
VCT.RC.M	0.001	0.013	0.017	0.017	0.017	(0.060)	NA
VCT.RC.L	0.085	0.141	0.155	0.161	(1.170)	NA	NA
VCT.SC.M	0.026	0.120	0.136	0.135	0.132	0.129	(0.340)
VCT.SC.L	0.005	0.014	0.014	0.015	0.015	0.015	(0.016)
VCT.SC.I	0.003	0.003	0.004	0.004	0.005	(0.042)	NA
VCS.SC.M	0.097	0.113	0.122	0.135	0.147	0.153	(1.720)
VCS.SC.L	0.083	0.105	0.120	0.138	0.139	0.135	(1.084)
VCS.SC.I	0.000	0.000	0.000	0.001	0.001	(0.011)	NA
SVO.RC.M	0.004	0.057	0.245	0.240	(0.231)	NA	NA
SVO.SC.M	0.000	0.008	0.012	0.029	0.027	(0.037)	NA
SOC.RC.M	0.001	0.004	0.039	0.038	0.031	(0.056)	NA
HZO.RC.M	(0.039)	NA	NA	NA	NA	NA	NA
HZO.RC.L	(0.229)	NA	NA	NA	NA	NA	NA
HZO.SC.M	0.000	0.000	0.000	(0.007)	NA	NA	NA
HZO.SC.L	(0.006)	NA	NA	NA	NA	NA	NA
HCT.SC.M	0.000	0.000	0.000	0.001	0.001	0.001	(0.003)
HCT.SC.L	0.001	0.002	0.009	0.010	0.010	0.009	(0.016)
HCT.SC.I	0.000	0.001	0.001	(0.039)	NA	NA	NA
HCS.SC.M	0.001	0.002	0.003	0.001	(0.005)	(0.166)	NA
HCS.SC.L	0.001	0.001	0.002	0.002	0.003	(0.021)	NA
PD.SC.M	0.119	0.237	0.236	0.231	0.200	0.176	(0.872)
SOC.SC.M	0.000	0.001	0.001	0.004	0.004	0.003	(0.003)

* A value of "NA" indicates that there are no associated efficiency levels at this level for this equipment class.
** 0.000 indicates savings are less than $0.0005 billion 2012$.
† Values in parentheses are negative values.

Table 10.4.8 Cumulative NPV Results by TSL Based on a 7-Percent Discount Rate (billion 2012$)

Equipment Class	*billion 2012$**,**,†				
	TSL 1	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
VOP.RC.M	0.016	0.099	0.466	0.461	(0.466)
VOP.RC.L	0.002	0.013	0.014	0.014	(0.062)
VOP.SC.M	0.003	0.005	0.027	0.025	(0.041)
VCT.RC.M	0.001	0.013	0.017	0.017	(0.060)
VCT.RC.L	0.141	0.155	0.161	0.161	(1.170)
VCT.SC.M	0.026	0.120	0.136	0.129	(0.340)
VCT.SC.L	0.014	0.014	0.015	0.015	(0.016)
VCT.SC.I	0.003	0.004	0.005	0.005	(0.042)
VCS.SC.M	0.113	0.135	0.153	0.153	(1.720)
VCS.SC.L	0.105	0.138	0.139	0.135	(1.084)
VCS.SC.I	0.000	0.001	0.001	0.001	(0.011)
SVO.RC.M	0.004	0.057	0.245	0.240	(0.231)
SVO.SC.M	0.008	0.012	0.029	0.027	(0.037)
SOC.RC.M	0.001	0.004	0.039	0.031	(0.056)
HZO.RC.M	–	–	–	–	(0.039)
HZO.RC.L	–	–	–	–	(0.229)
HZO.SC.M	0.000	0.000	0.000	0.000	(0.007)
HZO.SC.L	–	–	–	–	(0.006)
HCT.SC.M	0.000	0.001	0.001	0.001	(0.003)
HCT.SC.L	0.002	0.009	0.010	0.009	(0.016)
HCT.SC.I	0.000	0.001	0.001	0.001	(0.039)
HCS.SC.M	0.001	0.002	0.003	0.001	(0.166)
HCS.SC.L	0.002	0.002	0.003	0.003	(0.021)
PD.SC.M	0.119	0.119	0.237	0.176	(0.872)
SOC.SC.M	0.001	0.001	0.004	0.003	(0.003)
Total	**0.561**	**0.905**	**1.705**	**1.606**	**(6.735)**

* A "–" represents zero energy savings, since TSLs 1 to for the equipment classes HZO.RC.M, HZO.RC.L, and HZO.SC.L are associated with the baseline efficiency level.
**A value of 0.000 means NES values are less than $0.0005 billion 2012$.
† Values in parentheses are negative values.

Table 10.4.9 provides the NPV results for each CSL based on the 3-percent discount rate and electricity price forecasts from the *AEO2013* Reference Case. Table 10.4.10 presents the NPV results based on the 3-percent discount rate by TSL.

Table 10.4.9 Cumulative NPV Results by CSL Based on a 3-Percent Discount Rate (billion 2012$)

Equipment Class	Standard Level*,**,† *billion 2012$*						
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	0.037	0.233	1.144	1.140	(0.549)	NA	NA
VOP.RC.L	0.005	0.030	0.032	(0.104)	NA	NA	NA
VOP.SC.M	0.002	0.006	0.012	0.070	0.068	(0.053)	NA
VCT.RC.M	0.001	0.031	0.041	0.041	0.041	(0.100)	NA
VCT.RC.L	0.194	0.327	0.363	0.383	(2.017)	NA	NA
VCT.SC.M	0.059	0.283	0.331	0.332	0.330	0.326	(0.524)
VCT.SC.L	0.010	0.031	0.032	0.035	0.035	0.035	(0.020)
VCT.SC.I	0.007	0.007	0.011	0.011	0.012	(0.071)	NA
VCS.SC.M	0.221	0.259	0.279	0.316	0.354	0.398	(2.976)
VCS.SC.L	0.187	0.239	0.273	0.323	0.329	0.327	(1.837)
VCS.SC.I	0.000	0.001	0.001	0.001	0.002	(0.018)	NA
SVO.RC.M	0.008	0.137	0.615	0.608	(0.249)	NA	NA
SVO.SC.M	0.001	0.018	0.028	0.078	0.074	(0.043)	NA
SOC.RC.M	0.003	0.010	0.093	0.092	0.079	(0.078)	NA
HZO.RC.M	(0.071)	NA	NA	NA	NA	NA	NA
HZO.RC.L	(0.411)	NA	NA	NA	NA	NA	NA
HZO.SC.M	0.000	0.000	0.000	(0.013)	NA	NA	NA
HZO.SC.L	(0.012)	NA	NA	NA	NA	NA	NA
HCT.SC.M	0.000	0.000	0.000	0.002	0.002	0.002	(0.004)
HCT.SC.L	0.002	0.004	0.022	0.022	0.022	0.022	(0.023)
HCT.SC.I	0.001	0.002	0.003	(0.066)	NA	NA	NA
HCS.SC.M	0.003	0.005	0.007	0.006	(0.003)	(0.292)	NA
HCS.SC.L	0.001	0.002	0.004	0.006	0.007	(0.034)	NA
PD.SC.M	0.270	0.551	0.550	0.543	0.525	0.494	(1.406)
SOC.SC.M	0.001	0.002	0.002	0.009	0.009	0.008	(0.003)

* A value of "NA" is used to indicate that there are no associated efficiency levels at this level for this equipment class.
** 0.000 indicates savings are less than $0.0005 billion 2012$.
† Values in parentheses are negative values.

Table 10.4.10 Cumulative NPV Results by TSL Based on a 3-Percent Discount Rate (billion 2012$)

Equipment Class	*billion 2012$*,**,†				
	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	0.037	0.233	1.144	1.140	(0.549)
VOP.RC.L	0.005	0.030	0.032	0.032	(0.104)
VOP.SC.M	0.006	0.012	0.070	0.068	(0.053)
VCT.RC.M	0.001	0.031	0.041	0.041	(0.100)
VCT.RC.L	0.327	0.363	0.383	0.383	(2.017)
VCT.SC.M	0.059	0.283	0.331	0.326	(0.524)
VCT.SC.L	0.031	0.032	0.035	0.035	(0.020)
VCT.SC.I	0.007	0.011	0.012	0.012	(0.071)
VCS.SC.M	0.259	0.316	0.398	0.398	(2.976)
VCS.SC.L	0.239	0.323	0.329	0.327	(1.837)
VCS.SC.I	0.001	0.001	0.002	0.002	(0.018)
SVO.RC.M	0.008	0.137	0.615	0.608	(0.249)
SVO.SC.M	0.018	0.028	0.078	0.074	(0.043)
SOC.RC.M	0.003	0.010	0.093	0.079	(0.078)
HZO.RC.M	–	–	–	–	(0.071)
HZO.RC.L	–	–	–	–	(0.411)
HZO.SC.M	0.000	0.000	0.000	0.000	(0.013)
HZO.SC.L	–	–	–	–	(0.012)
HCT.SC.M	0.000	0.002	0.002	0.002	(0.004)
HCT.SC.L	0.004	0.022	0.022	0.022	(0.023)
HCT.SC.I	0.001	0.002	0.003	0.003	(0.066)
HCS.SC.M	0.003	0.005	0.007	0.006	(0.292)
HCS.SC.L	0.004	0.006	0.007	0.007	(0.034)
PD.SC.M	0.270	0.270	0.551	0.494	(1.406)
SOC.SC.M	0.002	0.002	0.009	0.008	(0.003)
Total	**1.285**	**2.118**	**4.165**	**4.067**	**(10.972)**

* A "–" represents zero energy savings, since TSLs 1 to 4 for the equipment classes HZO.RC.M, HZO.RC.L, and HZO.SC.L are associated with the baseline efficiency level.
**A value of 0.000 means NES values are less than $0.0005 billion 2012$.
† Values in parentheses are negative values.

10.5 ANNUALIZED NATIONAL COSTS AND BENEFITS

The benefits and costs of today's proposed standards, for equipment sold in 2017–2060, can be expressed in terms of annualized values. The annualized monetary values are the sum of (1) the annualized national economic value of the benefits from customer operation of equipment that meet the proposed standards (consisting primarily of operating cost savings from using less energy, minus increases in equipment purchase and installation costs, which is another way of representing customer NPV) and (2) the annualized monetary value of the benefits of emission reductions, including carbon dioxide (CO_2) emission reductions. The derivation of the monetary value of the benefits of emission reductions is described in chapter 14 of this NOPR TSD. The value of the CO_2 reductions, otherwise known as the Social Cost of Carbon (SCC), is calculated using a range of values per metric ton of CO_2 developed by a recent interagency process. The derivation of the time series of SCC values is discussed in appendix 14A of this NOPR TSD.

Although combining the values of operating savings and CO_2 reductions provides a useful perspective, two issues should be considered. First, the national operating cost savings are domestic U.S. customer monetary savings that occur as a result of market transactions, while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use quite different time frames for analysis. The national operating cost savings is measured for the lifetime of equipment shipped in the 30-year analysis period. The SCC values, on the other hand, reflect the present value of future climate-related impacts resulting from the emission of 1 ton of CO_2 in each year. These impacts go well beyond 2100.

10.5.1 Calculation Method

DOE uses a two-step calculation process to convert each time series of costs and benefits into annualized values. First, DOE calculates a present value in the "present" year used in discounting the NPV of total customer costs and savings.[b] For this calculation, DOE uses discount rates of 3 and 7 percent for all costs and benefits except for the value of CO_2 reductions. For the latter, DOE uses the discount rate appropriate for each SCC time series (see TSD chapter 16 for discussion).

$$PV_x = \sum_{t=y_1,y_T} \left(x(t) \cdot (1+r_x)^{y_{NPV}-t}\right)$$

Eq. 10.9

Where:

$x(t)$= time series under evaluation,
PV_x= present value of the time series x,
y_1= first year in the analysis period,
y_{T} = last year in the analysis period,
y_{NPV}= year to which the NPV of customers' costs and savings are being discounted, and
r_x = discount rate used to discount the annual values of time series x to year y_{NPV}.

In the second step, DOE calculates, from the present values, the fixed annual payments over a 30-year period, starting in the first year of the analysis period (*i.e.*, the compliance year), which yields the same present values with discount rates of 3 and 7 percent. This requires projecting the present values in the "present" year ahead to the compliance year. The fixed annual payments are the annualized values.

$$Ann_{x,r} = PV_x \cdot f_{y_1-y_{NPV},r} \cdot a_{30,r} = PV_x \cdot (1+r)^{y_1-y_{NPV}} \cdot \frac{r \cdot (1+r)^{30}}{(1+r)^{30}-1}$$

Eq. 10.10

Where:

$Ann_{x,r}$= annualized value of the time series x,
$f_{n,r}$ = factor to project a value n years ahead[c] with r discount rate, and
$a_{30,r}$ = factor to annualize present values over a 30-year period with r discount rate.

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[b] For the value of emissions reductions, DOE uses a time-series that corresponds to the time period used in calculating the operating cost savings (*i.e.*, through the final year in which equipment shipped are still operating).
[c] n is the number of years between the "present" year and the compliance year.

Although DOE calculates annualized values, this does not imply that the time series of cost and benefits from which the annualized values were determined would be a steady stream of payments.

10.5.2 Results for the Adopted Standards

The NOPR associated with this TSD states that DOE is adopting amended energy conservation standards for commercial refrigeration equipment that correspond to TSL 4. Estimates of annualized values for the proposed standards are shown in Table 10.5.1.

Table 10.5.1 Annualized Benefits and Costs of New and Amended Standards for Commercial Refrigeration Equipment Shipped in 2017–2046*

	Discount Rate	Primary Estimate	High Estimate	Low Estimate
		Monetized *million 2012$/year*		
Benefits				
Operating Cost Savings	7%	203	197	212
	3%	299	288	314
CO_2 Reduction at $12.9/t**	5%	19	19	19
CO_2 Reduction at $40.8/t**	3%	75	75	75
CO_2 Reduction at $62.2/t**	2.50%	114	114	114
CO_2 Reduction at $117.0/t**	3%	225	225	225
NO_X Reduction at $2636/t**	7%	3.75	3.75	3.75
	3%	5.33	5.33	5.33
Total (Operating Cost Savings, CO_2 Reduction and NO_X Reduction)†	7% plus CO_2 range	226 to 432	220 to 426	235 to 441
	7%	281	275	290
	3%	323 to 530	312 to 519	338 to 545
	3% plus CO_2 range	379	368	394
Costs				
Incremental Equipment Costs	7%	82	84	80
	3%	97	100	95
Net Benefits/Costs				
Total (Operating Cost Savings, CO_2 Reduction and NO_X Reduction, Minus Incremental Equipment Costs)†	7% plus CO_2 range	144 to 350	138 to 344	153 to 359
	7%	199	191	210
	3%	226 to 432	215 to 421	241 to 447
	3% plus CO_2 range	281	268	299

* This table presents the annualized costs and benefits associated with commercial refrigeration equipment shipped in 2017–2046. These results include benefits to customers that accrue after 2046 from the commercial refrigeration equipment purchased from 2017 through 2046. Costs incurred by manufacturers, some of which may be incurred before 2017 in preparation for the rule, are not directly included but are indirectly included as part of incremental equipment costs. In addition, incremental equipment costs reflect a medium decline rate for projected product price trends in the Primary Estimate, a low decline rate for projected equipment price trends in the Low Benefits Estimate, and a high decline rate for projected equipment price trends in the High Benefits Estimate. The methods used to derive projected price trends are explained in Appendix 10B.

** The CO_2 values represent global monetized 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 metric ton are the averages of SCC distributions calculated using 5-percent, 3-percent, and 2.5-percent discount rates, respectively. The value of $117.0/t represents the 95th percentile of the SCC distribution calculated using a 3-percent discount rate. The value for NO_x (in 2012$) is $2,639.

† Total benefits for both the 3-percent and 7-percent cases are derived using the SCC value calculated at a 3-percent discount rate, which is $40.8/t in 2015 (in 2012$). In the rows labeled as "7% plus CO_2 range" and "3% plus CO_2 range," the operating cost and NO_x benefits are calculated using the labeled discount rate, and those values are added to the full range of CO_2 values.

Appendix 10E of this NOPR TSD presents detailed Regulatory Information Service Center (RISC) & Office of Information and Regulatory Affairs, OMB (OIRA) Consolidated Information System (ROCIS) tables with annualized benefits and costs by equipment class grouping for all TSLs considered in this NOPR.

REFERENCES

1. U.S. Department of Energy—Energy Information Administration. *Commercial Demand Module of the National Energy Modeling System: Model Documentation 2012*. 2012. Washington, D.C. DOE/EIA-M066.

2. Energy Research Group / M.K. Jaccard & Associates. *Integration of GHG Emission Reduction Options using CIMS*. 2000. Vancouver, B.C. <http://www.emrg.sfu.ca/media/publications/Reports%20for%20Natural%20Resources%20Canada/Rollup.pdf>

3. U. S. Department of Energy—Energy Information Administration. *2013 Annual Energy Outlook*. 2013. Washington D.C. DOE/EIA-0383(2013). (Last accessed June 14, 2013.) <www.eia.gov/oiaf/aeo/tablebrowser/>

APPENDIX 10A. USER INSTRUCTIONS FOR NIA SPREADSHEET

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APPENDIX 10A. USER INSTRUCTIONS FOR NIA SPREADSHEET

10A.1 INTRODUCTION

The results of the national impact analysis (NIA) for commercial refrigeration equipment can be examined and reproduced using a Microsoft Excel spreadsheet available on the U.S. Department of Energy (DOE) Building Technologies (BT) website at www.eere.energy.gov/buildings/appliance_standards/commercial_products.html.

The spreadsheet enables the user to analyze up to 25 classes of commercial refrigeration equipment. The spreadsheet was designed and tested using Excel 2010.

10A.2 USER INSTRUCTIONS FOR NIA SPREADSHEET

The NIA spreadsheet performs calculations to forecast the change in national energy use due to an energy efficiency standard for commercial refrigeration equipment, and net present value (NPV) of the change in energy usage. The energy use and associated costs for a given standard are determined first by calculating the shipments and then calculating the energy use and costs for commercial refrigeration equipment shipped under that standard. The differences between the standards and base cases can then be compared and the overall energy savings and present values determined.

The NIA spreadsheet or workbook consists of the following worksheets (Table 10A.2.1). Some detailed worksheets are hidden to make it easier to examine the final results quickly, but can be retrieved by using the command option on the Excel 2010 Home tab: Format, Visibility – Hide & Unhide, Unhide Sheet.

Table 10A.2.1 Description of Tabs in the NIA Spreadsheet

Tab	Description
Analysis Flow	Figure that illustrates the calculations performed by the NIA spreadsheet.
Summary of Results	Worksheet that contains user input selections and, for the selected equipment class, a Summary table, Shipments graph, Cumulative Energy Savings and NPV graph, and an Annual Non-Discounted Savings Trend plot, which also contains a plot of discounted net savings by year.
Shipments-Weighted Data	Worksheet that contains calculated tables of both input data and results from the spreadsheet. For the notice of proposed rulemaking (NOPR) technical support document (TSD), data for many summary tables were compiled on this worksheet, including the Cumulative NPV and Energy Savings results.
Savings Summary	Accounting worksheet used to store the results of the shipments and energy savings calculations for an individual equipment class and up to seven efficiency levels (*e.g.*, Levels 2–8).
Details_Save (hidden)	Accounting worksheet used to tally the energy and cost savings year by year for an individual equipment class and standard level. The energy and cost savings in a single year are the difference between the base case energy use and costs for that year and the standards case energy use and costs in the same year.

Table 10A.2.1 (cont)

Tab	Description
Details_Stock (hidden)	Worksheet that keeps track of all surviving stock of commercial refrigeration equipment in an equipment class from the start year forward. Stock is updated for each year.
Initial Stock Details (hidden)	Worksheet that keeps track of all surviving stock of commercial refrigeration equipment in an equipment class from 2010 to the start year of the forecast (2017). Stock is updated for each year.
Shares Output 1, Shares Output 2, Shares Output 3, Shares Output 4, Shares Output 5, Shares Output 6, Shares Output 7 (all are hidden)	Seven worksheets that estimate percentage distribution shipments for all equipment classes of commercial refrigeration equipment, by efficiency level and year, from the start year of the forecast forward. Each worksheet applies to a different type of business (supermarkets, convenience and specialty stores, convenience stores with gas pumps, large multi-line retailers, limited service restaurants, full service restaurants, and other foodservice).
Shares Processing (hidden)	Worksheet that performs the detailed calculations based on annualized cost to estimate market shares of an equipment class, by efficiency level, in a business type, based on risk preferences of purchasers for a baseline market condition and up to seven candidate standard levels.
Input (hidden)	Worksheet that performs detailed calculations by risk preference class to estimate annualized cost for a newly purchased unit of an equipment class of commercial refrigeration equipment by efficiency level in a business type.
CRE Cost List	Contains input data on installed cost (total price), repair and maintenance cost, and annual electricity cost for units of commercial refrigeration equipment, calculated by the life-cycle cost (LCC) model by equipment class, business type, and efficiency level at U.S. average prices and market conditions.
Details_ Ship (hidden)	Calculates total shipments by efficiency level for an equipment class by year, given a candidate standard level. Also contains market weighted-average percentages of shipments by efficiency level of each equipment class of new commercial refrigeration equipment for baseline market conditions and up to seven candidate standard levels. Percentages are reported for each year from the start year forward.
Initial Shipments Detail (hidden)	Calculates total shipments by efficiency level and market weighted-average percentages of shipments by efficiency level of each equipment class of new commercial refrigeration equipment for baseline market conditions and up to seven candidate standard levels. Values are reported for each year from 2010 to the start year of the forecast (2017).
Shipments_Summary	Contains estimated shipments of an equipment class of commercial refrigeration equipment by efficiency level and year, for the last class/efficiency level combination calculated by the model. Also contains estimates of total shipments of each equipment class by year for each candidate standard level.
Base Product Market Share Calcd	Worksheet that performs calculations to estimate total market shipments by equipment class and year in the base case.
Product Shares	Contains percentages of overall commercial refrigeration equipment shipments (linear feet) by equipment class based on 2009 historical data. Populated from Summary of Results.
Econ Trends	Worksheet that contains historical and projected economic values as well as shipments data.

Table 10A.2.1 (cont)

Tab	Description
Equipment Parameters	Worksheet that contains the economic, energy, and size parameters for commercial refrigeration equipment.
Labels	Used as an interface between user inputs and the rest of the worksheets—do not modify this sheet
National Impacts Summary (hidden)	Tables for TSD, summarizing impacts, formatted for the document. Results linked from Shipment-Weighted Data worksheet.
ROCIS* (hidden)	Worksheet summarizing inputs and results from several NIA base and sensitivity runs, plus emissions and emission valuation results, for use in the Office of Management and Budget (OMB) process.
Shipments (hidden)	Worksheet that contains a single tabular summary of shipments for use in chapter 6 of the TSD.

*ROCIS is an acronym for Regulatory Information Service Center (RISC) and Office of Information and Regulatory Affairs (OIRA) Consolidated Information System.

Basic instructions for using the NIA spreadsheet are as follows:

1. Once the NIA spreadsheet file has been downloaded from the DOE BT website, open the file using Excel. If you receive a dialog box that asks whether you want to enable macros, select Yes. At the bottom of the Excel window, click on the tab for the worksheet Summary of Results.

2. Use Excel's View/Zoom commands at the top menu bar to size the display to your monitor.

3. You can change the model parameters listed in the gray box labeled "User defined inputs." The parameters are the following:

    a. Equipment Class: To change the value, select the menu box. A drop-down list appears. Select the desired equipment class. Many of the potential classes have no shipments, and are not being modeled. If you select one these classes, a warning will appear in the space immediately above the menu box and the first row in the summary of results will show up as zeroes; the cells will turn red and will be cross-hatched out.

    b. Efficiency Level: Select the efficiency level used in the non-discounted annual net impacts figure. The efficiency level must be less than or equal to the max tech level for the equipment class selected. If a higher standard level than max tech is selected, no results will be available for the levels above max tech.

    c. Max Tech: This value is currently set by the data contained within the model, not by the user, and is provided on the Summary of Results worksheet for the model user. (See the table found at cells S3 through Y30.) There is a routine within the model that requires the max tech be set at a level no greater than the currently modeled limit. Thus, max tech is presently not treated as a variable.

d. Discounting Reference Year: To change the year to which monetary values are discounted, select from the drop-down menu. For the NOPR phase, monetary values were discounted to 2013.

e. Growth in Energy Prices: To the change value, select the Growth in Energy Prices box. A drop-down menu pops up. Select the desired growth level (Constant, Reference, Low, or High). The scenarios refer to the Energy Information Administration's (EIA's) projected U.S. national average rates from *Annual Energy Outlook 2013*.[1]

f. Standard First Year: This is the first year in which the standard will take effect. This should be set to 2017 for the NOPR phase, but other options are available.

g. Discount Rate: To the change value, select the Discount Rate box. A drop-down menu pops up. Select the desired discount rate. Three options are provided: 3, 7 and 9 percent.

h. Price Learning: Also known as Experiential Learning, price learning controls the scenario for up-front prices for equipment.

4. Once the user parameters have been reset, the model must be re-run. To re-run the model for single equipment option, click the Update Values button. Note: The output values are not correctly updated until the Update Values button is clicked. To run all equipment classes, click the Run All Cases button. The Sales-Weighted Data worksheet is only updated when the Run All Cases button is used. This takes a few minutes. The Sales-Weighted Data worksheet is not updated by Update Values or by simply changing any of the input parameters.

5. If a new set of LCC results has been loaded into the CRE Cost List and Equipment Parameters worksheets, it will be necessary to recalculate the baseline equipment shipment shares by efficiency level in sheets Output1–Output7. To do this, click the Shares Processing button. The shares automatically update (this process takes about 3 minutes), but it will not be necessary to update again unless LCC input data change.

6. Tabular results are presented to the right of the "User defined inputs" box for the base case (Level 1) and the Level 2 through Level 8 standards cases. Tabular results are summarized as: (1) cumulative shipments; (2) percentage change in total shipments as efficiency level increases (currently, this does not change); (3) present value of national equipment cost savings in billions of dollars; (4) present value of national operating cost savings in billions of dollars; (5) national net present value in billions of dollars; and (6) cumulative national energy savings in quadrillion British thermal units (quads). Energy savings results for all standards cases are tabulated for two periods: 2017–2046 and 2017–2060. Net present value results are tabulated for 2017–2060, with equipment costs included for the period 2017–2046.

Graphical results are presented for the main tabular results. Two charts are provided for the given model parameters: (1) shipments forecasts for the base case and all standards cases and (2) national energy savings and net present values for all the standards cases.

For a given set of user-defined equipment choices and parameters, you can view the annual trend in the non-discounted net impacts for individual candidate standard levels. To view an efficiency level, select the drop-down menu bar with that title, and select the desired candidate standard level from the drop-down list. The annual purchase savings and operating cost savings are not discounted values. However, the net savings value in each year is shown as a discounted value.

REFERENCES

1. U.S. Department of Energy–Energy Information Administration. *Annual Energy Outlook 2013*. 2013. Washington D.C. DOE/EIA-0383(2013).

APPENDIX 10B. NATIONAL NET PRESENT VALUE USING ALTERNATIVE PRICE FORECASTS

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APPENDIX 10B. NATIONAL NET PRESENT VALUE USING ALTERNATIVE PRICE FORECASTS

10B.1 ALTERNATIVE NET PRESENT VALUES

The net present value (NPV) results presented in chapter 10 of this technical support document (TSD) reflect a price trend based on an experience curve derived using historical data on shipments and refrigeration equipment producer price index (PPI). The average annual rate of price decline in the default case for the 2017–2046 analysis period is 0.11 percent and is based on historical PPI data for refrigeration equipment between 1978–2012 as discussed in Appendix 8D. For the national impact analysis (NIA), 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 of 1978 to 2012. The low price forecast case is based on the lower end of the 95 percent confidence interval for an exponential fit to the nominal PPI series of 1978 to 2012. The average annual rate of price decline over the analysis period is 0.25 percent in the low price forecast case. In the high price forecast the average annual rate of change is an increase of 0.03 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 (TSLs) for commercial refrigeration equipment.

For the NPV sensitivity, DOE considered three product price forecast sensitivity cases: 1) a high price case based on the PPI trend of 1978–2012, 2) a low price case based on the PPI trend in 1978–2012, and 3) a constant real price case. Each price scenario 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 10B.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 10B.1.1 shows the price factor indices tabulated.

Table 10B.1.2 and Table 10B.1.3 provide NPV results for commercial refrigeration equipment at each TSL level based on the high price forecast case for 7 and 3 percent discount rates, respectively. Table 10B.1.4 and Table 10B.1.5 provide NPV results for commercial refrigeration equipment based on the low price forecast case at 7 and 3 percent discount rates, respectively. Table 10B.1.6 and Table 10B.1.7 provide NPV results for refrigeration systems based on a constant real price case at 7 and 3 percent discount rates, respectively. These results can be directly compared with the commercial refrigeration equipment NPV results using the default price decline scenario shown in chapter 10 of this TSD.

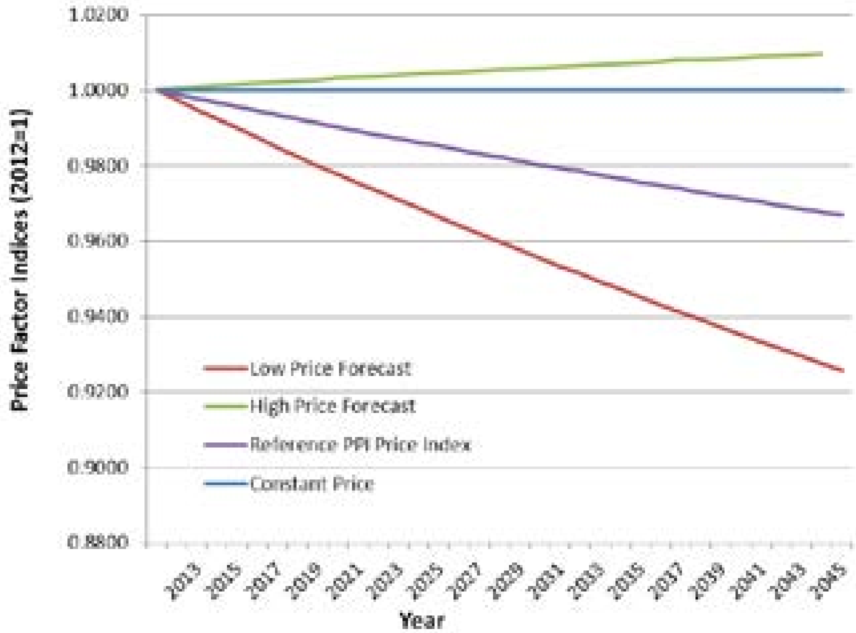

Figure 10B.1.1 Commercial Refrigeration Equipment Price Factor Indices for Default Case and Sensitivity Cases

Table 10B.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	1.000	1.000	1.000	1.0000
2013	0.999	1.000	0.997	1.0000
2014	0.998	1.001	0.995	1.0000
2015	0.997	1.001	0.992	1.0000
2016	0.996	1.001	0.990	1.0000
2017	0.995	1.002	0.987	1.0000
2018	0.993	1.002	0.985	1.0000
2019	0.992	1.002	0.982	1.0000
2020	0.991	1.003	0.980	1.0000
2021	0.990	1.003	0.978	1.0000
2022	0.989	1.003	0.975	1.0000
2023	0.988	1.003	0.973	1.0000
2024	0.987	1.004	0.971	1.0000
2025	0.986	1.004	0.969	1.0000
2026	0.985	1.004	0.967	1.0000
2027	0.984	1.005	0.964	1.0000
2028	0.983	1.005	0.962	1.0000
2029	0.982	1.005	0.960	1.0000
2030	0.981	1.006	0.958	1.0000
2031	0.980	1.006	0.955	1.0000
2032	0.979	1.006	0.953	1.0000
2033	0.978	1.006	0.951	1.0000
2034	0.978	1.007	0.949	1.0000
2035	0.977	1.007	0.947	1.0000
2036	0.976	1.007	0.945	1.0000
2037	0.975	1.007	0.943	1.0000
2038	0.974	1.008	0.941	1.0000
2039	0.973	1.008	0.939	1.0000
2040	0.972	1.008	0.937	1.0000
2041	0.971	1.009	0.935	1.0000
2042	0.970	1.009	0.933	1.0000
2043	0.969	1.009	0.931	1.0000
2044	0.969	1.009	0.929	1.0000
2045	0.968	1.010	0.928	1.0000
2046	0.967	1.010	0.926	1.0000

Table 10B.1.2 Commercial Refrigeration Equipment: Net Present Value in Billions (2012$) at a 7 Percent Discount Rate – High Price Scenario

	billion 2012$				
	TSL1	**TSL2**	**TSL3**	**TSL4**	**TSL5**
VOP.RC.M	0.016	0.099	0.462	0.456	(0.491)
VOP.RC.L	0.002	0.013	0.013	0.013	(0.064)
VOP.SC.M	0.003	0.005	0.027	0.025	(0.043)
VCT.RC.M	0.001	0.013	0.017	0.016	(0.062)
VCT.RC.L	0.140	0.154	0.160	0.160	(1.202)
VCT.SC.M	0.026	0.119	0.135	0.127	(0.352)
VCT.SC.L	0.014	0.014	0.015	0.015	(0.016)
VCT.SC.I	0.003	0.004	0.005	0.005	(0.043)
VCS.SC.M	0.113	0.135	0.150	0.150	(1.767)
VCS.SC.L	0.105	0.137	0.138	0.133	(1.115)
VCS.SC.I	0.000	0.001	0.001	0.001	(0.011)
SVO.RC.M	0.004	0.056	0.242	0.237	(0.244)
SVO.SC.M	0.008	0.012	0.029	0.026	(0.039)
SOC.RC.M	0.001	0.004	0.039	0.030	(0.058)
SOC.SC.M	0.001	0.001	0.004	0.003	(0.003)
HZO.RC.M	-	-	-	-	(0.040)
HZO.RC.L	-	-	-	-	(0.234)
HZO.SC.M	0.000	0.000	0.000	0.000	(0.008)
HZO.SC.L	-	-	-	-	(0.007)
HCT.SC.M	0.000	0.001	0.001	0.001	(0.003)
HCT.SC.L	0.002	0.009	0.010	0.009	(0.017)
HCT.SC.I	0.000	0.001	0.001	0.001	(0.040)
HCS.SC.M	0.001	0.002	0.003	0.001	(0.170)
HCS.SC.L	0.002	0.002	0.003	0.003	(0.022)
PD.SC.M	0.119	0.119	0.236	0.170	(0.901)
Total	0.559	0.900	1.689	1.583	(6.952)

"-" represents zero energy savings, since TSLs 1 to 4 for equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level.
*A value of 0.000 means national energy savings (NES) values are less than $0.0005 billion 2012$.

Table 10B.1.3 Commercial Refrigeration Equipment: Net Present Value in Billions (2012$) at a 3 Percent Discount Rate – High Price Scenario

	billion 2012$				
	TSL1	**TSL2**	**TSL3**	**TSL4**	**TSL5**
VOP.RC.M	0.036	0.232	1.136	1.131	(0.603)
VOP.RC.L	0.005	0.030	0.032	0.032	(0.108)
VOP.SC.M	0.006	0.012	0.069	0.067	(0.057)
VCT.RC.M	0.001	0.030	0.041	0.040	(0.104)
VCT.RC.L	0.326	0.361	0.380	0.380	(2.086)
VCT.SC.M	0.059	0.281	0.328	0.321	(0.551)
VCT.SC.L	0.031	0.032	0.035	0.035	(0.022)
VCT.SC.I	0.007	0.011	0.012	0.012	(0.074)
VCS.SC.M	0.259	0.314	0.391	0.391	(3.076)
VCS.SC.L	0.238	0.322	0.327	0.324	(1.905)
VCS.SC.I	0.001	0.001	0.002	0.002	(0.019)
SVO.RC.M	0.008	0.136	0.609	0.602	(0.277)
SVO.SC.M	0.018	0.028	0.077	0.072	(0.047)
SOC.RC.M	0.003	0.010	0.093	0.078	(0.083)
SOC.SC.M	0.002	0.002	0.009	0.008	(0.004)
HZO.RC.M	-	-	-	-	(0.073)
HZO.RC.L	-	-	-	-	(0.423)
HZO.SC.M	0.000	0.000	0.000	0.000	(0.014)
HZO.SC.L	-	-	-	-	(0.012)
HCT.SC.M	0.000	0.002	0.002	0.002	(0.004)
HCT.SC.L	0.004	0.022	0.022	0.022	(0.024)
HCT.SC.I	0.001	0.002	0.003	0.003	(0.068)
HCS.SC.M	0.003	0.005	0.007	0.006	(0.301)
HCS.SC.L	0.004	0.006	0.007	0.007	(0.036)
PD.SC.M	0.269	0.269	0.548	0.482	(1.469)
Total	1.281	2.107	4.132	4.019	(11.438)

"-" represents zero energy savings, since TSLs 1 to 4 for equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level.
*A value of 0.000 means NES values are less than $0.0005 billion 2012$.

Table 10B.1.4 Commercial Refrigeration Equipment: Net Present Value in Billions (2012$) at a 7 Percent Discount Rate – Low Price Scenario

	billion 2012$				
	TSL1	**TSL2**	**TSL3**	**TSL4**	**TSL5**
VOP.RC.M	0.016	0.100	0.470	0.465	(0.442)
VOP.RC.L	0.002	0.013	0.014	0.014	(0.060)
VOP.SC.M	0.003	0.005	0.027	0.026	(0.039)
VCT.RC.M	0.001	0.013	0.017	0.017	(0.058)
VCT.RC.L	0.142	0.156	0.162	0.162	(1.138)
VCT.SC.M	0.026	0.120	0.138	0.131	(0.327)
VCT.SC.L	0.014	0.014	0.015	0.015	(0.015)
VCT.SC.I	0.003	0.005	0.005	0.005	(0.040)
VCS.SC.M	0.114	0.136	0.156	0.156	(1.675)
VCS.SC.L	0.105	0.139	0.140	0.136	(1.053)
VCS.SC.I	0.000	0.001	0.001	0.001	(0.010)
SVO.RC.M	0.004	0.057	0.247	0.243	(0.218)
SVO.SC.M	0.008	0.012	0.030	0.027	(0.035)
SOC.RC.M	0.001	0.004	0.039	0.031	(0.053)
SOC.SC.M	0.001	0.001	0.004	0.003	(0.003)
HZO.RC.M	-	-	-	-	(0.038)
HZO.RC.L	-	-	-	-	(0.224)
HZO.SC.M	0.000	0.000	0.000	0.000	(0.007)
HZO.SC.L	-	-	-	-	(0.006)
HCT.SC.M	0.000	0.001	0.001	0.001	(0.002)
HCT.SC.L	0.002	0.009	0.010	0.009	(0.015)
HCT.SC.I	0.000	0.001	0.001	0.001	(0.038)
HCS.SC.M	0.001	0.002	0.003	0.002	(0.162)
HCS.SC.L	0.002	0.002	0.003	0.003	(0.021)
PD.SC.M	0.119	0.119	0.238	0.181	(0.843)
Total	0.563	0.910	1.721	1.628	(6.523)

"-" represents zero energy savings, since TSLs 1 to 4 for equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level.
*A value of 0.000 means NES values are less than $0.0005 billion 2012$.

Table 10B.1.5 Commercial Refrigeration Equipment: Net Present Value in Billions (2012$) at a 3 Percent Discount Rate – Low Price Scenario

	billion 2012$				
	TSL1	**TSL2**	**TSL3**	**TSL4**	**TSL5**
VOP.RC.M	0.037	0.234	1.152	1.149	(0.498)
VOP.RC.L	0.005	0.030	0.032	0.032	(0.100)
VOP.SC.M	0.006	0.012	0.071	0.069	(0.049)
VCT.RC.M	0.001	0.031	0.041	0.041	(0.096)
VCT.RC.L	0.328	0.365	0.386	0.386	(1.949)
VCT.SC.M	0.059	0.285	0.334	0.330	(0.497)
VCT.SC.L	0.031	0.032	0.035	0.035	(0.018)
VCT.SC.I	0.007	0.011	0.012	0.012	(0.069)
VCS.SC.M	0.260	0.317	0.404	0.404	(2.878)
VCS.SC.L	0.239	0.325	0.331	0.330	(1.771)
VCS.SC.I	0.001	0.001	0.002	0.002	(0.018)
SVO.RC.M	0.009	0.138	0.620	0.614	(0.221)
SVO.SC.M	0.018	0.028	0.079	0.075	(0.038)
SOC.RC.M	0.003	0.010	0.094	0.080	(0.073)
SOC.SC.M	0.002	0.002	0.009	0.008	(0.003)
HZO.RC.M	-	-	-	-	(0.069)
HZO.RC.L	-	-	-	-	(0.399)
HZO.SC.M	0.000	0.000	0.000	0.000	(0.013)
HZO.SC.L	-	-	-	-	(0.011)
HCT.SC.M	0.000	0.002	0.002	0.002	(0.004)
HCT.SC.L	0.004	0.022	0.022	0.022	(0.021)
HCT.SC.I	0.001	0.002	0.004	0.004	(0.064)
HCS.SC.M	0.003	0.005	0.007	0.006	(0.283)
HCS.SC.L	0.004	0.006	0.007	0.007	(0.033)
PD.SC.M	0.270	0.270	0.553	0.505	(1.345)
Total	1.288	2.129	4.198	4.113	(10.521)

"-" represents zero energy savings, since TSLs 1 to 4 for equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level.
*A value of 0.000 means NES values are less than $0.0005 billion 2012$.

Table 10B.1.6 Commercial Refrigeration Equipment: Net Present Value in Billions (2012$) at a 7 Percent Discount Rate – Constant Real Price Scenario

	billion 2012$				
	TSL1	**TSL2**	**TSL3**	**TSL4**	**TSL5**
VOP.RC.M	0.016	0.099	0.463	0.457	(0.485)
VOP.RC.L	0.002	0.013	0.014	0.014	(0.063)
VOP.SC.M	0.003	0.005	0.027	0.025	(0.042)
VCT.RC.M	0.001	0.013	0.017	0.016	(0.062)
VCT.RC.L	0.140	0.154	0.160	0.160	(1.195)
VCT.SC.M	0.026	0.119	0.135	0.127	(0.349)
VCT.SC.L	0.014	0.014	0.015	0.015	(0.016)
VCT.SC.I	0.003	0.004	0.005	0.005	(0.042)
VCS.SC.M	0.113	0.135	0.151	0.151	(1.757)
VCS.SC.L	0.105	0.137	0.138	0.134	(1.108)
VCS.SC.I	0.000	0.001	0.001	0.001	(0.011)
SVO.RC.M	0.004	0.056	0.243	0.237	(0.241)
SVO.SC.M	0.008	0.012	0.029	0.026	(0.039)
SOC.RC.M	0.001	0.004	0.039	0.030	(0.057)
SOC.SC.M	0.001	0.001	0.004	0.003	(0.003)
HZO.RC.M	-	-	-	-	(0.040)
HZO.RC.L	-	-	-	-	(0.233)
HZO.SC.M	0.000	0.000	0.000	0.000	(0.007)
HZO.SC.L	-	-	-	-	(0.007)
HCT.SC.M	0.000	0.001	0.001	0.001	(0.003)
HCT.SC.L	0.002	0.009	0.010	0.009	(0.017)
HCT.SC.I	0.000	0.001	0.001	0.001	(0.039)
HCS.SC.M	0.001	0.002	0.003	0.001	(0.169)
HCS.SC.L	0.002	0.002	0.003	0.003	(0.022)
PD.SC.M	0.119	0.119	0.236	0.172	(0.894)
Total	0.560	0.901	1.693	1.588	(6.903)

"-" represents zero energy savings, since TSLs 1 to 4 for equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level.
*A value of 0.000 means NES values are less than $0.0005 billion 2012$.

Table 10B.1.7 Commercial Refrigeration Equipment: Net Present Value in Billions (2012$) at a 3 Percent Discount Rate – Constant Real Price Scenario

	billion 2012$				
	TSL1	**TSL2**	**TSL3**	**TSL4**	**TSL5**
VOP.RC.M	0.036	0.232	1.138	1.133	(0.590)
VOP.RC.L	0.005	0.030	0.032	0.032	(0.107)
VOP.SC.M	0.006	0.012	0.070	0.067	(0.056)
VCT.RC.M	0.001	0.030	0.041	0.040	(0.103)
VCT.RC.L	0.326	0.362	0.381	0.381	(2.070)
VCT.SC.M	0.059	0.282	0.329	0.322	(0.545)
VCT.SC.L	0.031	0.032	0.035	0.035	(0.021)
VCT.SC.I	0.007	0.011	0.012	0.012	(0.073)
VCS.SC.M	0.259	0.314	0.393	0.393	(3.053)
VCS.SC.L	0.239	0.322	0.328	0.325	(1.889)
VCS.SC.I	0.001	0.001	0.002	0.002	(0.019)
SVO.RC.M	0.008	0.136	0.610	0.604	(0.271)
SVO.SC.M	0.018	0.028	0.077	0.073	(0.046)
SOC.RC.M	0.003	0.010	0.093	0.078	(0.082)
SOC.SC.M	0.002	0.002	0.009	0.008	(0.004)
HZO.RC.M	-	-	-	-	(0.073)
HZO.RC.L	-	-	-	-	(0.420)
HZO.SC.M	0.000	0.000	0.000	0.000	(0.013)
HZO.SC.L	-	-	-	-	(0.012)
HCT.SC.M	0.000	0.002	0.002	0.002	(0.004)
HCT.SC.L	0.004	0.022	0.022	0.022	(0.024)
HCT.SC.I	0.001	0.002	0.003	0.003	(0.068)
HCS.SC.M	0.003	0.005	0.007	0.006	(0.299)
HCS.SC.L	0.004	0.006	0.007	0.007	(0.036)
PD.SC.M	0.269	0.269	0.549	0.485	(1.454)
Total	1.282	2.110	4.139	4.030	(11.331)

"-" represents zero energy savings, since TSLs 1 to 4 for equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level.
*A value of 0.000 means NES values are less than $0.0005 billion 2012$.

APPENDIX 10C. TRIAL STANDARD LEVELS AND STANDARDS EQUATIONS

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10C.1 INTRODUCTION

The U.S. Department of Energy (DOE) carried out the life-cycle cost (LCC) analysis and national impact analysis (NIA) by defining efficiency levels within each equipment class of commercial refrigeration equipment. These efficiency levels were chosen from the design option levels defined as part of the engineering analysis. These design option levels were defined based on the available energy efficiency technologies in the current market and are, generally, different for different equipment classes. Therefore, in general, the efficiency levels belonging to different equipment classes are independent of one another. For example, Efficiency Level 4 of one equipment class is not related to, or is dependent of the Efficiency Level 4 belonging to another equipment class (see chapter 8 of the technical support document (TSD) for criteria used in the selection of efficiency levels from the available design option levels).

DOE developed trial standard levels (TSLs) by combining selected efficiency levels from each equipment class into TSL groupings based on a set of specific criteria. This process enables the grouping of efficiency levels across all equipment classes such that the efficiency levels belonging to a TSL grouping all have a certain uniform characteristic or criterion associated with them. DOE evaluated the national impacts, such as national energy savings (NES), net present value (NPV), employment impacts, impacts on manufacturers, and environmental impacts, at each TSL. Based on the results, DOE proposes to set the standard at a particular TSL.

This appendix describes DOE's method for selecting TSLs for commercial refrigeration equipment. The following sections describe the criteria used for TSL selection and standard level equations associated with each TSL.

10C.2 TRIAL STANDARD LEVEL SELECTION CRITERIA

DOE selected five TSLs for this rulemaking based on the following criteria:

1. TSL 5 was set at the maximum technologically feasible (max-tech) level for each equipment class.

2. TSL 4 was chosen so as to include the highest efficiency level, within each equipment class, with a positive NPV at a 7-percent discount rate.

3. TSL 3 was chosen to represent the efficiency level within each equipment class with the highest NPV at a 7-percent discount rate.

4. For TSL 2, the efficiency levels were chosen to be one level below the efficiency levels belonging to TSL 3. However, in the instances where such a choice had NPV values close to the efficiency level belonging to TSL 3, the next lower level was chosen.

5. For TSL 1, the efficiency levels were chosen to be one level below the efficiency levels belonging to TSL 2. However, in the instances where such a choice had NPV values close to the efficiency level belonging to TSL 2, the next lower level was chosen.

Table 10C.2.1 presents the efficiency levels within each equipment class that belong to the five TSL groupings. Equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L, have only two efficiency levels defined for the LCC analysis and NIA. Level 1 is the baseline efficiency level and Level 2 is the max-tech level. Also, the NPV values at Level 2 were negative and, therefore, did not satisfy the criteria for TSL 3 and TSL 4. Hence, Level 2, for each of these three equipment classes, was assigned to TSL 5, and Level 1 was allocated to TSL 1 through TSL 4. Table 10C.2.2 presents the design options at each TSL. Design options are generally cumulative as described in chapter 5, and particular technologies incorporated at a given TSL (*e.g.*, TSL 4) dependent on equipment class. At TSL 5, the max tech, the final design option incorporated in most equipment classes was the use of Vacuum Insulated Panel (VIP) insulation.

Table 10C.2.1 TSL and Efficiency Levels Mapping

Equipment Class		Intermediate Level*	Intermediate Level**	Max NPV***	Max Eff. Level with Pos-NPV†	Max-Tech
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
VOP.RC.L	Level 1	Level 2	Level 3	Level 4	Level 4	Level 5
VOP.SC.M	Level 1	Level 3	Level 4	Level 5	Level 6	Level 7
VCT.RC.M	Level 1	Level 2	Level 3	Level 4	Level 6	Level 7
VCT.RC.L	Level 1	Level 3	Level 4	Level 5	Level 5	Level 6
VCT.SC.M	Level 1	Level 2	Level 3	Level 4	Level 7	Level 8
VCT.SC.L	Level 1	Level 3	Level 4	Level 5	Level 7	Level 8
VCT.SC.I	Level 1	Level 3	Level 5	Level 6	Level 6	Level 7
VCS.SC.M	Level 1	Level 3	Level 5	Level 7	Level 7	Level 8
VCS.SC.L	Level 1	Level 3	Level 5	Level 6	Level 7	Level 8
VCS.SC.I	Level 1	Level 3	Level 5	Level 6	Level 6	Level 7
SVO.RC.M	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
SVO.SC.M	Level 1	Level 3	Level 4	Level 5	Level 6	Level 7
SOC.RC.M	Level 1	Level 2	Level 3	Level 4	Level 6	Level 7
HZO.RC.M‡	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
HZO.RC.L‡	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
HZO.SC.M	Level 1	Level 2	Level 2	Level 3	Level 4	Level 5
HZO.SC.L‡	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
HCT.SC.M	Level 1	Level 3	Level 5	Level 6	Level 7	Level 8
HCT.SC.L	Level 1	Level 3	Level 4	Level 5	Level 7	Level 8
HCT.SC.I	Level 1	Level 2	Level 3	Level 4	Level 4	Level 5
HCS.SC.M	Level 1	Level 2	Level 3	Level 4	Level 5	Level 7
HCS.SC.L	Level 1	Level 4	Level 5	Level 6	Level 6	Level 7
PD.SC.M	Level 1	Level 2	Level 2	Level 3	Level 7	Level 8
SOC.SC.M	Level 1	Level 3	Level 4	Level 5	Level 7	Level 8

"Level" stands for "Efficiency Level."
* TSL generally chosen as one level below TSL 2, but could be lower if the immediate lower level is too close to TSL 2 when the NPV values are compared.
**TSL generally chosen as one level below TS L3, but could be lower if the immediate lower level is too close to TSL 3 when the NPV values are compared.
***Efficiency level that has the highest NPV at a 7-percent discount rate.
†Highest efficiency level with a positive NPV at a 7-percent discount rate.
‡TSLs 1 through 4 for these equipment classes do not satisfy the criteria for the corresponding TSL selection. They were assigned the baseline efficiency level for TSLs 1 through 4.

Table 10C.2.2 Design Options at Each TSL

Equipment Class	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	ECM Evaporator Fan, Super T8 Lighting	Night Curtains	Enhanced Evaporator Coil	LED with Occupancy Sensor	1/2" insulation	VIP
VOP.RC.L	ECM Evaporator Fan, Night Curtains, Super T8 Lighting	Enhanced Evaporator Coil	LED with Occupancy Sensor	1/2" insulation	Same as TSL 3	VIP
VOP.SC.M	High-Efficiency Compressor, Enhanced Condenser Coil, ECM Evaporator Fan, Super T8 Lighting	Night Curtains	PSC Condenser Fan	ECM Condenser Fan	1/2" insulation	VIP
VCT.RC.M	LED, PSC Evaporator Fan	ECM Evaporator Fan	High-Performance Door	Occupancy Sensor	1/2" insulation, Enhanced Evaporator Coil	VIP
VCT.RC.L	LED, ECM Evaporator Fan	High-Performance Door, LED with Occupancy Sensor	1/2" insulation	Enhanced Evaporator Coil	Same as TSL 3	VIP
VCT.SC.M	LED, High-Efficiency Compressor	Enhanced Evaporator Coil, ECM Evaporator Fan	High-Performance Door, PSC Condenser Fan	Occupancy Sensor	ECM Condenser Fan, 1/2" insulation, Enhanced Evaporator Coil	VIP
VCT.SC.L	Baseline	LED, Enhanced Condenser Coil, High-Efficiency Compressor, ECM Evaporator Fan, High-Performance Door	Enhanced Evaporator Coil	Occupancy Sensor	1/2" insulation, ECM Condenser Fan	VIP
VCT.SC.I	LED, Enhanced Evaporator Coil, Enhanced Condenser Coil, High-Efficiency Compressor, ECM Fan Motor	High-Perform Door, PSC Condenser Fan	Occupancy Sensor, ECM Con Fan	1/2" insulation	Same as TSL 3	VIP

ECM = Electronically Commutated Motors   PSC = Permanent Split Capacitor Motor   LED = Light Emitting Diode   VIP = Vacuum Insulated Panels
High-Efficiency Compressor = High-Efficiency Reciprocating Compressor   Occupancy Sensor = Occupancy Sensor (with LED lighting)

Table 10C.2.2 (cont)

Equipment Class	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VCS.SC.M	Baseline	Enhanced Condenser Coil, ECM Evaporator Fan, High-Efficiency Compressor	Enhanced Evaporator Coil, PSC Condenser Fan	ECM Condenser Fan, 1/2" insulation	Same as TSL 3	VIP
VCS.SC.L	Baseline	Enhanced Condenser Coil, ECM Evaporator Fan, High-Efficiency Compressor	Enhanced Evaporator Coil, 1/2" insulation	PSC Condenser Fan	ECM Condenser Fan	VIP
VCS.SC.I	Enhanced Condenser Coil, PSC Evaporator Fan, Enhanced Evaporator Coil	ECM Evaporator Fan, High-Efficiency Compressor	PSC Condenser Fan, 1/2" insulation	ECM Condenser Fan	Same as TSL 3	VIP
SVO.RC.M	ECM Evaporator Fan, Super T8 Lighting	Enhanced Evaporator Coil	Night Curtains	LED with Occupancy Sensor	1/2" insulation	VIP
SVO.SC.M	High-Efficiency Compressor, Enhanced Cond Coil, Super T8 Lighting, ECM Evaporator Fan, PSC Cond Fan	Enhanced Evap Coil, Night Curtains	ECM Cond Fan	LED with Occupancy Sensor	1/2" insulation	VIP
SOC.RC.M	PSC Evaporator Fan, Super T8 Lighting	ECM Evaporator Fan	Enhanced Evaporator Coil	LED	1/2" insulation, High-Performance Door	VIP
HZO.RC.M	ECM Evaporator Fan, Enhanced Evaporator Coil, 1/2" insulation	Baseline	Baseline	Baseline	Baseline	VIP
HZO.RC.L	ECM Evaporator Fan, Enhanced Evaporator Coil, 1/2" insulation	Baseline	Baseline	Baseline	Baseline	VIP
HZO.SC.M	High-Efficiency Compressor, Enhanced Condenser Coil, Enhanced Evaporator Coil, ECM Evaporator Fan	PSC Condenser Fan	Same as TSL 1	ECM Condenser Fan	1/2" insulation	VIP

ECM = Electronically Commutated Motors PSC = Permanent Split Capacitor Motor LED = Light Emitting Diode VIP = Vacuum Insulated Panels
High-Efficiency Compressor = High-Efficiency Reciprocating Compressor Occupancy Sensor = Occupancy Sensor (with LED lighting)

Table 10C.2.2 (cont)

Equipment Class	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
HZO.SC.L	High-Efficiency Compressor, Enhanced Condenser Coil, Enhanced Evaporator Coil, ECM Evaporator Fan, PSC Condenser Fan, 1/2" insulation	Baseline	Baseline	Baseline	Baseline	VIP
HCT.SC.M	Baseline	Enhanced Condenser Coil, High-Efficiency Compressor	PSC Condenser Fan, High-Performance Door	ECM Condenser Fan	1/2" insulation	VIP
HCT.SC.L	Baseline	Enhanced Condenser Coil, High-Efficiency Compressor	High-Performance Door, PSC Condenser Fan	ECM Condenser Fan	1/2" insulation	VIP
HCT.SC.I	High-Efficiency Compressor, PSC Condenser Fan	High-Performance Door	ECM Condenser Fan	1/2" insulation	Same as TSL 3	VIP
HCS.SC.M	Baseline	Enhanced Condenser Coil	High-Efficiency Compressor	PSC Condenser Fan	ECM Condenser Fan	1/2" insulation, VIP
HCS.SC.L	Baseline	Enhanced Condenser Coil, High-Efficiency Compressor, PSC Condenser Fan	ECM Condenser Fan	1/2" insulation	Same as TSL 3	VIP
PD.SC.M	Baseline	LED, Enhanced Condenser Coil, ECM Evaporator Fan, High-Efficiency Compressor,	Same as TSL 1	High-Performance Door	ECM Condenser Fan, Occupancy Sensor, 1/2" insulation, Enhanced Evaporator Coil	VIP
SOC.SC.M	High-Efficiency Compressor, Enhanced Condenser Coil	Super T8 Lighting, ECM Evaporator Fan	ECM Condenser Fan	LED	1/2" insulation, High-Performance Door	VIP

ECM = Electronically Commutated Motors PSC = Permanent Split Capacitor Motor LED = Light Emitting Diode VIP = Vacuum Insulated Panels
High-Efficiency Compressor = High-Efficiency Reciprocating Compressor Occupancy Sensor = Occupancy Sensor (with LED lighting)

Table 10C.2.3 presents the mapping between the TSLs and design option levels. Table 10C.2.4 presents the mapping between efficiency levels and design option levels.

Table 10C.2.3 TSL and Design Option Levels Mapping

Equipment Class	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	SB	AD5	AD6	AD7	AD8	AD9
VOP.RC.L	SB	AD6	AD7	AD8	AD8	AD9
VOP.SC.M	SB	AD9	AD10	AD11	AD12	AD13
VCT.RC.M	SB	AD4	AD5	AD6	AD8	AD9
VCT.RC.L	SB	AD6	AD7	AD8	AD8	AD9
VCT.SC.M	SB	AD6	AD8	AD9	AD12	AD13
VCT.SC.L	AD1	AD7	AD8	AD9	AD12	AD13
VCT.SC.I	SB	AD9	AD11	AD12	AD12	AD13
VCS.SC.M	AD1	AD5	AD7	AD9	AD9	AD10
VCS.SC.L	AD1	AD5	AD7	AD8	AD9	AD10
VCS.SC.I	SB	AD6	AD8	AD9	AD9	AD10
SVO.RC.M	SB	AD5	AD6	AD7	AD8	AD9
SVO.SC.M	SB	AD9	AD10	AD11	AD12	AD13
SOC.RC.M	SB	AD4	AD5	AD6	AD8	AD9
HZO.RC.M	SB	SB	SB	SB	SB	AD6
HZO.RC.L	SB	SB	SB	SB	SB	AD6
HZO.SC.M	SB	AD7	AD7	AD8	AD9	AD10
HZO.SC.L	SB	SB	SB	SB	SB	AD10
HCT.SC.M	AD1	AD3	AD5	AD6	AD7	AD8
HCT.SC.L	AD1	AD3	AD4	AD5	AD7	AD8
HCT.SC.I	SB	AD4	AD5	AD6	AD6	AD7
HCS.SC.M	AD1	AD2	AD3	AD4	AD5	AD7
HCS.SC.L	AD1	AD4	AD5	AD6	AD6	AD7
PD.SC.M	SB	AD6	AD6	AD7	AD12	AD13
SOC.SC.M	SB	AD8	AD9	AD10	AD12	AD13

"AD" represents "Design Option Level." For example, AD12 represents Design Option Level 12. For details on the design options associated with each design option level within each equipment class, see TSD chapter 5.
"SB" stands for "Standards Baseline." See TSD chapter 8 for a discussion related to the selection of the standards baseline.

Table 10C.2.4 Efficiency Levels and Design Option Levels Mapping

Equipment Class	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	SB	AD5	AD6	AD7	AD8	AD9	NA	NA
VOP.RC.L	SB	AD6	AD7	AD8	AD9	NA	NA	NA
VOP.SC.M	SB	AD8	AD9	AD10	AD11	AD12	AD13	AD13
VCT.RC.M	SB	AD4	AD5	AD6	AD7	AD8	AD9	NA
VCT.RC.L	SB	AD5	AD6	AD7	AD8	AD9	NA	NA
VCT.SC.M	SB	AD6	AD8	AD9	AD10	AD11	AD12	AD13
VCT.SC.L	AD1	AD4	AD7	AD8	AD9	AD10	AD12	AD13
VCT.SC.I	SB	AD8	AD9	AD10	AD11	AD12	AD13	NA
VCS.SC.M	AD1	AD4	AD5	AD6	AD7	AD8	AD9	AD10
VCS.SC.L	AD1	AD4	AD5	AD6	AD7	AD8	AD9	AD10
VCS.SC.I	SB	AD5	AD6	AD7	AD8	AD9	AD10	NA
SVO.RC.M	SB	AD5	AD6	AD7	AD8	AD9	NA	NA
SVO.SC.M	SB	AD8	AD9	AD10	AD11	AD12	AD13	NA
SOC.RC.M	SB	AD4	AD5	AD6	AD7	AD8	AD9	NA
HZO.RC.M	SB	AD6	NA	NA	NA	NA	NA	NA
HZO.RC.L	SB	AD6	NA	NA	NA	NA	NA	NA
HZO.SC.M	SB	AD7	AD8	AD9	AD10	NA	NA	NA
HZO.SC.L	SB	AD10	NA	NA	NA	NA	NA	NA
HCT.SC.M	AD1	AD2	AD3	AD4	AD5	AD6	AD7	AD8
HCT.SC.L	AD1	AD2	AD3	AD4	AD5	AD6	AD7	AD8
HCT.SC.I	SB	AD4	AD5	AD6	AD7	NA	NA	NA
HCS.SC.M	AD1	AD2	AD3	AD4	AD5	AD6	AD7	NA
HCS.SC.L	AD1	AD2	AD3	AD4	AD5	AD6	AD7	NA
PD.SC.M	SB	AD6	AD7	AD8	AD9	AD10	AD12	AD13
SOC.SC.M	SB	AD6	AD8	AD9	AD10	AD11	AD12	AD13

"AD" represents "Design Option Level." For example, AD12 represents Design Option Level 12. For details on the design options associated with each design option level within each equipment class, see TSD chapter 5.
"SB" stands for "Standards Baseline". See TSD chapter 8 for a discussion related to the selection of standards baseline.
"NA" stands for not applicable, and is used where the number of efficiency levels for an equipment class is less than 8.
"Level" stands for "Efficiency Level."

DOE considered two additional criteria for TSL groupings. One criterion was to group the efficiency levels with the lowest LCC (Minimum-LCC grouping) and the other criterion was to group the highest efficiency levels with payback periods less than 3 years (Payback Period grouping). The Minimum-LCC grouping had the same efficiency levels as TSL 3 except for three equipment classes, which had efficiency levels one level higher than TSL 3. The net NES and NPV values associated with this grouping were almost identical to those of TSL 3. The Payback Period grouping was infeasible because certain equipment classes did not have any efficiency levels with payback periods less than 3 years. For the equipment classes that had efficiency levels with payback periods less than 3 years, the efficiency levels were higher than those of TSL 3 in some equipment classes, lower in some others, and equal in the rest. Neither of these additional TSL groupings showed a distinct advantage over the five TSL groupings described above. Therefore, these additional groupings were discarded for the downstream analyses.

10C.3 TRIAL STANDARD LEVEL EQUATIONS

Because of the equipment size variation within each equipment class and the use of daily energy consumption as the efficiency metric, DOE developed a methodology to express efficiency standards in terms of a normalizing metric. DOE utilized one of two normalizing metrics for each equipment class: (1) volume (V) or (2) total display area (TDA). The use of these two normalization metrics allowed for the development of the energy conservation standard in the form of a linear equation that could be used to represent the entire range of equipment sizes within a given equipment class. DOE retained the respective normalization metric (TDA or volume) previously used in the Energy Policy Act of 2005 (EPACT 2005), the January 2009 final rule standards for each covered equipment class, or the American Energy Manufacturing Technical Corrections Act (AEMTCA). (42 U.S.C. 6313(c)(2)–(3)); 74 FR 1092, 1093 (Jan. 9, 2009); (42 U.S.C. 6313(c)(4)).

In its January 2009 final rule, DOE developed offset factors as a way to adjust the energy efficiency requirements for smaller equipment in each equipment class analyzed. These offset factors, which form the y-intercept on a plot of each standard level equation (representing a fictitious case of zero volume or zero TDA), accounted for certain components of the refrigeration load (such as conduction end effects) that remain constant even when equipment sizes vary. These constant loads affect smaller cases disproportionately. The offset factors were intended to approximate these constant loads and provide a fixed end point in an equation that describes the relationship between energy consumption and the corresponding normalization metric. 74 FR at 1118–19 (Jan. 9, 2009).The standard levels equations prescribed by EPACT 2005 also contained similar fixed parts not multiplied by the volume metric and which correspond to these offset factors. In this notice of proposed rulemaking, DOE modified the January 2009 final rule (74 FR at 1118–19 (Jan. 9, 2009)) and EPACT 2005 offset factors at each TSL to reflect the proportional changes in energy consumption for each equipment class, as modeled in the engineering analysis. See chapter 5 of the TSD for further details and discussion of offset factors.

For the equipment classes covered under this rulemaking, the standards equation at each TSL is proposed in the form of maximum daily energy consumption (MDEC) (in kilowatt-hours (kWh) per day) normalized by a volume (V) or TDA metric. These equations take the form:

$MDEC = A \times TDA + B$ (for equipment using TDA as a normalizing metric)

or

$MDEC = A \times V + B$ (for equipment using volume as a normalizing metric)

For equipment classes directly analyzed in the engineering analysis, the offset factor, *B*, was calculated for each class (see chapter 5 of the TSD for discussion of offset factors). The slope, *A*, was derived based on the offset factor, *B*, and the calculated daily energy consumption (CDEC) of the representative unit modeled in the engineering analysis for that equipment class (presented in Table 10C.3.1). The standards equations (presented in Table 10C.3.2 at each TSL) would be used to prescribe the MDEC for equipment of different sizes within a given equipment class.

Table 10C.3.1 CDEC Values by TSL for Representative Units Analyzed in the Engineering Analysis for Each Primary Equipment Class

Equipment Class	CDEC Values by TSL *kWh/day*				
	TSL 1	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
VOP.RC.M	46.84	44.33	35.71	35.51	35.06
VOP.RC.L	106.22	101.03	100.51	100.51	98.87
VOP.SC.M	30.03	29.60	26.70	26.62	26.46
VCT.RC.M	15.56	8.10	6.26	5.97	5.49
VCT.RC.L	31.13	30.58	30.29	30.29	28.85
VCT.SC.M	7.56	4.08	3.24	2.97	2.68
VCT.SC.L	13.48	13.30	12.44	12.09	11.57
VCT.SC.I	17.45	16.36	16.14	16.14	15.37
VCS.SC.M	2.36	2.17	1.81	1.81	1.39
VCS.SC.L	7.26	6.75	6.66	6.56	5.71
VCS.SC.I	18.24	17.79	17.64	17.64	16.53
SVO.RC.M	36.11	33.85	27.71	27.57	27.26
SVO.SC.M	25.74	25.36	23.29	23.24	23.12
SOC.RC.M	25.62	24.97	20.43	20.15	19.93
HZO.RC.M	14.43	14.43	14.43	14.43	14.17
HZO.RC.L	33.10	33.10	33.10	33.10	32.22
HZO.SC.M	14.76	14.76	14.60	14.49	14.26
HZO.SC.L	30.12	30.12	30.12	30.12	29.91
HCT.SC.M	1.87	0.84	0.75	0.67	0.49
HCT.SC.L	4.11	1.83	1.77	1.57	1.18
HCT.SC.I	3.22	3.07	2.86	2.86	2.13
HCS.SC.M	0.65	0.60	0.56	0.50	0.25
HCS.SC.L	1.61	1.46	1.27	1.27	0.74
PD.SC.M	3.90	3.90	2.23	1.64	1.42
SOC.SC.M	27.04	26.80	22.02	21.70	21.41

Table 10C.3.2 Equations Representing the Standards at Each TSL for All Primary Equipment Classes

Equipment Class	Trial Standard Levels for Primary Equipment Classes Analyzed					
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VCT.RC.L	0.56 × TDA + 2.61	0.45 × TDA + 2.08	0.44 × TDA + 2.05	0.43 × TDA + 2.03	0.43 × TDA + 2.03	0.41 × TDA + 1.93
VOP.RC.M	0.82 × TDA + 4.07	0.8 × TDA + 3.99	0.76 × TDA + 3.78	0.61 × TDA + 3.04	0.61 × TDA + 3.03	0.6 × TDA + 2.99
SVO.RC.M	0.83 × TDA + 3.18	0.82 × TDA + 3.16	0.77 × TDA + 2.96	0.63 × TDA + 2.42	0.63 × TDA + 2.41	0.62 × TDA + 2.38
HZO.RC.L	0.57 × TDA + 6.88	0.57 × TDA + 6.88	0.57 × TDA + 6.88	0.57 × TDA + 6.88	0.57 × TDA + 6.88	0.55 × TDA + 6.7
HZO.RC.M	0.35 × TDA + 2.88	0.35 × TDA + 2.88	0.35 × TDA + 2.88	0.35 × TDA + 2.88	0.35 × TDA + 2.88	0.34 × TDA + 2.83
VCT.RC.M	0.22 × TDA + 1.95	0.21 × TDA + 1.87	0.11 × TDA + 0.97	0.08 × TDA + 0.75	0.08 × TDA + 0.72	0.07 × TDA + 0.66
VOP.RC.L	2.27 × TDA + 6.85	2.23 × TDA + 6.72	2.12 × TDA + 6.39	2.11 × TDA + 6.36	2.11 × TDA + 6.36	2.07 × TDA + 6.26
SOC.RC.M	0.51 × TDA + 0.11	0.5 × TDA + 0.11	0.49 × TDA + 0.11	0.4 × TDA + 0.09	0.39 × TDA + 0.08	0.39 × TDA + 0.08
VOP.SC.M	1.74 × TDA + 4.71	1.7 × TDA + 4.61	1.68 × TDA + 4.54	1.51 × TDA + 4.1	1.51 × TDA + 4.09	1.5 × TDA + 4.06
SVO.SC.M	1.73 × TDA + 4.59	1.67 × TDA + 4.42	1.64 × TDA + 4.35	1.51 × TDA + 4.	1.5 × TDA + 3.99	1.5 × TDA + 3.97
HZO.SC.L	1.92 × TDA + 7.08	1.92 × TDA + 7.08	1.92 × TDA + 7.08	1.92 × TDA + 7.08	1.92 × TDA + 7.08	1.91 × TDA + 7.03
HZO.SC.M	0.77 × TDA + 5.55	0.77 × TDA + 5.54	0.77 × TDA + 5.54	0.76 × TDA + 5.48	0.75 × TDA + 5.44	0.74 × TDA + 5.35
HCT.SC.I	0.56 × TDA + 0.43	0.55 × TDA + 0.42	0.52 × TDA + 0.4	0.49 × TDA + 0.37	0.49 × TDA + 0.37	0.36 × TDA + 0.28
VCT.SC.I	0.67 × TDA + 3.29	0.56 × TDA + 2.77	0.53 × TDA + 2.6	0.52 × TDA + 2.56	0.52 × TDA + 2.56	0.5 × TDA + 2.44
VCS.SC.I	0.38 × V + 0.88	0.36 × V + 0.84	0.35 × V + 0.82	0.35 × V + 0.81	0.35 × V + 0.81	0.33 × V + 0.76
VCT.SC.M	0.12 × V + 3.34	0.1 × V + 2.74	0.05 × V + 1.48	0.04 × V + 1.17	0.04 × V + 1.07	0.03 × V + 0.97
VCT.SC.L	0.53 × V + 2.92	0.25 × V + 1.35	0.24 × V + 1.33	0.23 × V + 1.25	0.22 × V + 1.21	0.21 × V + 1.16
VCS.SC.M	0.06 × V + 1.31	0.03 × V + 0.69	0.03 × V + 0.64	0.03 × V + 0.53	0.03 × V + 0.53	0.02 × V + 0.41
VCS.SC.L	0.21 × V + 0.72	0.14 × V + 0.48	0.13 × V + 0.44	0.13 × V + 0.44	0.13 × V + 0.43	0.11 × V + 0.38
HCT.SC.M	0.06 × V + 1.73	0.05 × V + 1.42	0.02 × V + 0.63	0.02 × V + 0.57	0.02 × V + 0.51	0.01 × V + 0.38
HCT.SC.L	0.36 × V + 1.98	0.29 × V + 1.57	0.13 × V + 0.70	0.12 × V + 0.68	0.11 × V + 0.6	0.08 × V + 0.45
HCS.SC.M	0.03 × V + 0.54	0.02 × V + 0.49	0.02 × V + 0.45	0.02 × V + 0.41	0.02 × V + 0.37	0.01 × V + 0.18
HCS.SC.L	0.2 × V + 0.69	0.15 × V + 0.53	0.14 × V + 0.48	0.12 × V + 0.42	0.12 × V + 0.42	0.07 × V + 0.24
PD.SC.M	0.13 × V + 3.51	0.07 × V + 1.98	0.07 × V + 1.98	0.04 × V + 1.13	0.03 × V + 0.83	0.03 × V + 0.72
SOC.SC.M	0.6 × TDA + 1.0	0.4 × TDA + 0.67	0.4 × TDA + 0.66	0.33 × TDA + 0.54	0.32 × TDA + 0.53	0.32 × TDA + 0.53

In addition to the 25 primary equipment classes analyzed, DOE intends to amend standards for 24 secondary classes of commercial refrigeration equipment covered in this rulemaking that were not directly analyzed in the engineering analysis. DOE's approach involves extension multipliers developed using the primary equipment classes analyzed and a set of matched-pair analyses performed during the January 2009 final rule analysis. In addition, DOE believes that standards for certain primary equipment classes can be directly applied to similar secondary equipment classes. Chapter 5 of the TSD discusses the development of the extension multipliers.

Using the extension multiplier approach, DOE developed an additional set of TSLs and associated equations for the secondary equipment classes, as shown in Table 10C.3.3. The TSLs shown in Table 10C.3.3 do not necessarily satisfy the criteria spelled out in section 10C.2 because the analyses required to evaluate the criteria were not performed for those classes. DOE is presenting the standards equations developed for each TSL for all 49 equipment classes to allow interested parties to better review the ramifications of each TSL across the range of product sizes on the market.

Table 10C.3.3 Equations Representing the Standards at Each TSL for All Secondary Equipment Classes

Equipment Class	Trial Standard Levels for Secondary Equipment Classes Analyzed					
	Baseline	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.I	2.89 × TDA + 8.7	2.83 × TDA + 8.54	2.69 × TDA + 8.12	2.68 × TDA + 8.08	2.68 × TDA + 8.08	2.63 × TDA + 7.95
SVO.RC.L	2.27 × TDA + 6.85	2.23 × TDA + 6.72	2.12 × TDA + 6.39	2.11 × TDA + 6.36	2.11 × TDA + 6.36	2.07 × TDA + 6.26
SVO.RC.I	2.89 × TDA + 8.7	2.83 × TDA + 8.54	2.69 × TDA + 8.12	2.68 × TDA + 8.08	2.68 × TDA + 8.08	2.63 × TDA + 7.95
HZO.RC.I	0.72 × TDA + 8.74	0.72 × TDA + 8.74	0.72 × TDA + 8.74	0.72 × TDA + 8.74	0.72 × TDA + 8.74	0.7 × TDA + 8.5
VOP.SC.L	4.37 × TDA + 11.82	4.27 × TDA + 11.57	4.21 × TDA + 11.4	3.8 × TDA + 10.29	3.79 × TDA + 10.26	3.77 × TDA + 10.2
VOP.SC.I	5.55 × TDA + 15.02	5.43 × TDA + 14.69	5.35 × TDA + 14.48	4.83 × TDA + 13.06	4.81 × TDA + 13.03	4.78 × TDA + 12.95
SVO.SC.L	4.34 × TDA + 11.51	4.18 × TDA + 11.09	4.12 × TDA + 10.93	3.78 × TDA + 10.04	3.77 × TDA + 10.01	3.76 × TDA + 9.96
SVO.SC.I	5.52 × TDA + 14.63	5.31 × TDA + 14.09	5.23 × TDA + 13.88	4.8 × TDA + 12.75	4.79 × TDA + 12.72	4.77 × TDA + 12.65
HZO.SC.I	2.44 × TDA + 9.0	2.44 × TDA + 9.0	2.44 × TDA + 9.0	2.44 × TDA + 9.0	2.44 × TDA + 9.0	2.42 × TDA + 8.93
SOC.RC.L	1.08 × TDA + 0.22	1.05 × TDA + 0.23	1.02 × TDA + 0.22	0.84 × TDA + 0.18	0.83 × TDA + 0.18	0.82 × TDA + 0.18
SOC.RC.I	1.26 × TDA + 0.26	1.23 × TDA + 0.27	1.2 × TDA + 0.26	0.98 × TDA + 0.21	0.97 × TDA + 0.21	0.96 × TDA + 0.21
SOC.SC.I	1.76 × TDA + 0.36	1.72 × TDA + 0.37	1.68 × TDA + 0.36	1.37 × TDA + 0.3	1.35 × TDA + 0.29	1.34 × TDA + 0.29
VCT.RC.I	0.66 × TDA + 3.05	0.52 × TDA + 2.44	0.51 × TDA + 2.39	0.51 × TDA + 2.37	0.51 × TDA + 2.37	0.48 × TDA + 2.26
HCT.RC.M	0.16 × TDA + 0.13	0.16 × TDA + 0.12	0.15 × TDA + 0.12	0.14 × TDA + 0.11	0.14 × TDA + 0.11	0.1 × TDA + 0.08
HCT.RC.L	0.34 × TDA + 0.26	0.33 × TDA + 0.26	0.32 × TDA + 0.24	0.3 × TDA + 0.23	0.3 × TDA + 0.23	0.22 × TDA + 0.17
HCT.RC.I	0.4 × TDA + 0.31	0.39 × TDA + 0.3	0.37 × TDA + 0.29	0.35 × TDA + 0.27	0.35 × TDA + 0.27	0.26 × TDA + 0.2
VCS.RC.M	0.11 × V + 0.26	0.11 × V + 0.24	0.1 × V + 0.24	0.1 × V + 0.24	0.1 × V + 0.24	0.1 × V + 0.22
VCS.RC.L	0.23 × V + 0.54	0.22 × V + 0.51	0.22 × V + 0.5	0.21 × V + 0.5	0.21 × V + 0.5	0.2 × V + 0.46
VCS.RC.I	0.27 × V + 0.63	0.26 × V + 0.6	0.25 × V + 0.58	0.25 × V + 0.58	0.25 × V + 0.58	0.23 × V + 0.54
HCS.SC.I	0.38 × V + 0.88	0.36 × V + 0.84	0.35 × V + 0.82	0.35 × V + 0.81	0.35 × V + 0.81	0.33 × V + 0.76
HCS.RC.M	0.11 × V + 0.26	0.11 × V + 0.24	0.1 × V + 0.24	0.1 × V + 0.24	0.1 × V + 0.24	0.1 × V + 0.22
HCS.RC.L	0.23 × V + 0.54	0.22 × V + 0.51	0.22 × V + 0.5	0.21 × V + 0.5	0.21 × V + 0.5	0.2 × V + 0.46
HCS.RC.I	0.27 × V + 0.63	0.26 × V + 0.6	0.25 × V + 0.58	0.25 × V + 0.58	0.25 × V + 0.58	0.23 × V + 0.54
SOC.SC.L	0.75 × V + 4.10	0.84 × TDA + 1.4	0.83 × TDA + 1.39	0.68 × TDA + 1.14	0.67 × TDA + 1.12	0.66 × TDA + 1.11

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APPENDIX 10D. FULL-FUEL-CYCLE MULTIPLIERS

10D.1 INTRODUCTION

This appendix summarizes the methods used to calculate full-fuel-cycle (FFC) energy savings expected to result from potential standards. The FFC measure includes point-of-use (site) energy, the energy losses associated with generation, transmission, and distribution of electricity, and the energy consumed in extracting, processing, and transporting or distributing primary fuels. The U.S. Department of Energy's (DOE's) traditional approach encompassed only site energy and the energy losses associated with generation, transmission, and distribution of electricity. Per DOE's 2011 *Statement of Policy for Adopting Full Fuel Cycle Analyses*, DOE now uses FFC measures of energy use and emissions in its energy conservation standards analyses. 76 FR 51281 (Aug. 18, 2011), as amended at 77 FR 49701 (Aug. 17, 2012). This appendix summarizes the methods used to incorporate the FFC impacts into the analysis.

This analysis uses several different terms to reference energy use. The physical sources of energy are the primary fuels such as coal, natural gas, liquid fuels, etc. Primary energy is equal to the heat content (British thermal units) of the primary fuels used to provide an end-use service. Site energy use is defined as the energy consumed at the point-of-use in a building or industrial process. Where natural gas and petroleum fuels are consumed at the site (for example, in a furnace), site energy is identical to primary energy, with both equal to the heat content of the primary fuel consumed. For electricity, site energy is measured in kilowatt-hours. In this case, the primary energy is equal to the quadrillion British thermal units (quads) of primary energy required to generate and deliver the site electricity. This primary energy is calculated by multiplying the site kilowatt-hours by the site-to-power plant energy use factor*,* given in chapter 10. For the FFC analysis, the upstream energy use is defined as the energy consumed in extracting, processing, and transporting or distributing primary fuels. FFC energy use is the sum of primary plus upstream energy use.

Both primary fuels and electricity are used in upstream activities. The treatment of electricity in fuel cycle analysis must distinguish between electricity generated by fossil fuels and uranium, and electricity generated from renewable fluxes (wind, solar, and hydro). For the former, the upstream fuel cycle impacts are derived from the amount of fuel consumed at the power plant. For the latter, no fuel *per se* is used, so there is no upstream component.

10D.2 METHODOLOGY

The mathematical approach is discussed in the paper *A Mathematical Analysis of Full Fuel Cycle Energy Use*,[1] and details on the fuel production chain analysis are presented in the paper *Projections of Full Fuel Cycle Energy and Emissions Metrics*.[2] The following discussion provides a brief summary of the methods used to calculate FFC energy.

When all energy quantities are normalized to the same units, the FFC energy use can be represented as the product of the primary energy use and an *FFC multiplier*. The FFC multiplier is defined mathematically as a function of a set of parameters representing the energy intensity and material losses at each production stage. These parameters depend only on physical data, so the calculations do not require any assumptions about prices or other economic data. While in general these parameter values may vary by geographic region, for this analysis national averages are used.

In the notation below, the indices x and y are used to indicate fuel type, with x=c for coal, x=g for natural gas, x=p for petroleum fuels, x=u for uranium, and x=r for renewable fluxes. The fuel cycle parameters are the following:

- a_x is the quantity of fuel x burned per unit of electricity output, on average, for grid electricity. The calculation of a_x includes a factor to account for transmission and distribution system losses.
- b_y is the amount of grid electricity used in production of fuel y, in megawatt-hours per physical unit of fuel y.
- c_{xy} is the amount of fuel x consumed in producing one unit of fuel y.
- q_x is the heat content of fuel x (million British thermal units/physical unit)
- $z_x(s)$ is the emissions intensity for fuel x (mass of pollutant s per physical unit of x)

The parameters are calculated as a function of time with an annual time step; hence, a time series of annual values is used to estimate the FFC energy and emissions savings in each year of the analysis period. Fossil fuel quantities are converted to energy units using the heat content factors qx. To convert electricity in kilowatt-hours to primary energy units, on-site electricity consumption is multiplied by the site-to-power plant energy use factor. The site-to-power plant energy use factor is defined as the ratio of the total primary energy consumption by the electric power sector (in quads) divided by the total electricity generation in each year.

The FFC multiplier is denoted μ (mu). A separate multiplier is calculated for each fuel used on site. A multiplier is also calculated for electricity reflecting the fuel mix used in its generation. The multipliers are dimensionless numbers that are applied to primary energy savings to obtain the FFC energy savings. The upstream component of the energy savings is proportional to (μ-1). The fuel type is denoted by a subscript on the multiplier μ.

For DOE's appliance standards energy savings estimates, the fuel cycle analysis methodology is designed to make use of data and projections published in the *Annual Energy Outlook* (*AEO*). Table 10D.2.1 provides a summary of the *AEO* data used as inputs to the different parameter calculations. The *AEO* does not provide all the information needed to estimate total energy use in the fuel production chain. *Projections of Full Fuel Cycle Energy and Emissions Metrics* describes the additional data sources used to complete the analysis. However, the time dependence in the FFC multipliers arises exclusively from variables taken from the *AEO*.[2] The FFC analysis for CRE used data from *Annual Energy Outlook 2013* (*AEO2013*).[3] *AEO2013* provides projections to 2040.

Table 10D.2.1 Dependence of FFC Parameters on *AEO* Inputs

Parameter	Fuel	*AEO* Table	Variables
qx	all	Conversion Factors	MMBtu per physical unit
ax	all	Electricity Supply, Disposition, Prices, and Emissions	Generation by fuel type
		Energy Consumption by Sector and Source	Electric power sector energy consumption
bc, cnc, cpc	coal	Coal Production by Region and Type	Production by coal type and sulfur content
bp, cnp, cpp	petroleum	Refining Industry Energy Consumption	Refining only energy use
		Liquid Fuels Supply and Disposition	Crude supply by source
		International Liquids Supply and Disposition	Crude oil imports
		Oil and Gas Supply	Crude oil domestic production
cnn	natural gas	Oil and Gas Supply	US dry gas production
		Natural Gas Supply, Disposition and Prices	Pipeline, lease and plant fuel
zx	all	Electricity Supply, Disposition, Prices and Emissions	Power sector emissions

10D.3 FULL-FUEL-CYCLE ENERGY MULTIPLIERS

FFC energy multipliers are presented in Table 10D.3.1 for selected years. To extend the analysis period beyond 2040, the last year in the *AEO2013* projection, the multipliers are assumed constant through the final year of the analysis period. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation over the forecast period.

Table 10D.3.1 Full-Fuel-Cycle Energy Multipliers (Based on *AEO2013*)

	2015	2020	2025	2030	2035	2040
Electricity (power plant primary energy use)	1.042	1.041	1.040	1.040	1.041	1.040
Natural Gas (site)	1.103	1.101	1.100	1.098	1.099	1.100
Petroleum Fuels (site)	1.132	1.140	1.148	1.158	1.166	1.168

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10E.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 public rulemaking (NOPR) for commercial refrigeration equipment (CRE). In Table 10E.1.2 through Table 10E.1.11, the top half of the table presents the NPV values that would result if the U.S. Department of Energy (DOE) were to add the estimates of the potential economic benefits resulting from reduced carbon dioxide (CO_2) and nitrogen oxide (NO_x) emissions to the NPV of customer savings calculated for each TSL considered in this NOPR, at both a 7 percent and 3 percent discount rate.

Although combining the values of operating savings and CO_2 reductions provides a useful perspective, two issues should be considered. First, the national operating savings are domestic U.S. consumer monetary savings that occur as a result of market transactions while the value of CO_2 reductions is based on a global value. Second, the assessments of operating cost savings and CO_2 savings are performed with different methods that use quite different time frames for analysis. The national operating cost savings is measured for the lifetime of products shipped in the 30-year analysis period. The social cost of carbon values, on the other hand, reflect the present value of future climate-related impacts resulting from the emission of one ton of CO_2 in each year. These impacts go well beyond 2100.

The benefits and costs of today's considered standard levels, for products sold in 2017 through 2046, also can be expressed in terms of annualized values. The annualized monetary values shown in Table 10E.1.2 through Table 10E.1.11 present the sum of 1) the annualized national economic value, expressed in 2012 dollars (2012$), of the benefits from customer 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 customer NPV) and 2) the annualized monetary value of the benefits of emission reductions, including CO_2 emission reductions. These results tables address all TSLs and equipment class groups. For the sake of brevity, the 25 equipment classes have been grouped into 7 groups as shown in Table 10E.1.1.

Table 10E.1.1 Equipment Class Groupings

Group Name	Equipment Classes Belonging to the Group
VOP.RC Equipment	VOP.RC.M and VOP.RC.L
SVO.RC and HZO.RC Equipment	SVO.RC.M, HZO.RC.M, and HZO.RC.L
Open Self-Contained Equipment	VOP.SC.M, SVO.SC.M, HZO.SC.M, and HZO.SC.L
EPCA Refrigerators and Pull-Down Equipment	VCS.SC.M, VCT.SC.M, HCS.SC.M, HCT.SC.M, PD.SC.M, and SOC.SC.M
EPCA Freezers	VCS.SC.L, VCT.SC.L, HCS.SC.L, and HCT.SC.L
VCT.RC and SOC.RC Equipment	VCT.RC.M, VCT.RC.L, and SOC.RC.M
Ice-cream Freezers	VCT.SC.I, VCS.SC.I, and HCT.SC.I

Table 10E.1.2 Cumulative and Annualized Benefits and Costs of Considered Standard Levels for CRE Units Shipped in the Period 2017–2046 (TSL 1, 3 Percent Discount Rate)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-Cream Freezers	*Total*
Cumulative Results									
Energy Savings									
Full-Fuel Cycle	*quads*	0.008	0.002	0.005	0.108	0.049	0.063	0.002	0.236
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.009	0.002	0.007	0.047	0.019	0.057	0.001	0.142
Operating Cost Savings	*billion 2012$*	0.051	0.011	0.031	0.640	0.297	0.388	0.009	1.427
NPV	*billion 2012$*	0.041	0.008	0.025	0.593	0.278	0.331	0.008	1.285
Emissions Savings (physical)									
Full-Fuel Cycle									
CO_2	*million metric ton*	0.446	0.094	0.278	5.917	2.706	3.429	0.084	12.953
NOx	*kilo-ton*	0.659	0.138	0.410	8.741	3.997	5.066	0.124	19.135
Hg	*ton*	0.001	0.000	0.001	0.012	0.006	0.007	0.000	0.027
SO_2	*kilo-ton*	0.570	0.120	0.355	7.558	3.456	4.380	0.107	16.546
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	2.501	0.525	1.558	33.183	15.175	19.231	0.472	72.644
3% dr, average	*million 2012$*	12.227	2.568	7.615	162.207	74.179	94.005	2.306	355.107
2.5% dr, average	*million 2012$*	19.924	4.184	12.409	264.320	120.876	153.183	3.758	578.655
3% dr, 95th perc	*million 2012$*	36.992	7.768	23.039	490.747	224.423	284.405	6.978	1074.352
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.2 to 0.6	0.0 to 0.1	0.1 to 0.4	2.3 to 7.6	1.1 to 3.5	1.3 to 4.4	0.0 to 0.1	5.1 to 16.7
3% dr, average	*million 2012$*	0.9 to 2.8	0.2 to 0.6	0.5 to 1.8	11.4 to 37.3	5.2 to 17.1	6.6 to 21.6	0.2 to 0.5	24.9 to 81.7
2.5% dr, average	*million 2012$*	1.4 to 4.6	0.3 to 1.0	0.9 to 2.9	18.5 to 60.8	8.5 to 27.8	10.7 to 35.2	0.3 to 0.9	40.5 to 133.1
3% dr, 95th perc	*million 2012$*	2.6 to 8.5	0.5 to 1.8	1.6 to 5.3	34.4 to 112.9	15.7 to 51.6	19.9 to 65.4	0.5 to 1.6	75.2 to 247.1
NOx (3% dr)									
At 468 2012$/ton	*million 2012$*	0.155	0.033	0.097	2.059	0.941	1.193	0.029	4.507
At 2,639 2012$/ton	*million 2012$*	0.875	0.184	0.545	11.606	5.308	6.726	0.165	25.408
At 4,809 2012$/ton	*million 2012$*	1.594	0.335	0.993	21.149	9.672	12.256	0.301	46.299
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.044	0.009	0.026	0.628	0.294	0.351	0.009	1.362
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.054	0.011	0.033	0.767	0.358	0.432	0.011	1.665
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.062	0.013	0.037	0.869	0.404	0.491	0.012	1.889
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.080	0.017	0.049	1.105	0.512	0.628	0.016	2.406

Table 10E.1.2 (cont)

	Units	**VOP.RC Equipment**	**SVO.RC and HZO.RC Equipment**	**Open Self-Contained Equipment**	**EPCA Refrigerators and Pull-Down Equipment**	**EPCA Freezers**	**VCT.RC and SOC.RC Equipment**	**Ice-Cream Freezers**	**Total**
Annualized Results									
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.000	0.000	0.000	0.002	0.001	0.003	0.000	0.007
Operating Cost Savings	*billion 2012$*	0.003	0.001	0.002	0.032	0.015	0.019	0.000	0.071
NPV	*billion 2012$*	0.002	0.000	0.001	0.029	0.014	0.016	0.000	0.064
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	0.155	0.033	0.097	2.056	0.940	1.191	0.029	4.501
3% dr, average	*million 2012$*	0.606	0.127	0.377	8.035	3.674	4.656	0.114	17.590
2.5% dr, average	*million 2012$*	0.929	0.195	0.578	12.321	5.634	7.140	0.175	26.972
3% dr, 95th perc	*million 2012$*	1.832	0.385	1.141	24.308	11.116	14.088	0.346	53.216
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.01 to 0.04	0.00 to 0.01	0.01 to 0.02	0.14 to 0.47	0.07 to 0.22	0.08 to 0.27	0.00 to 0.01	0.32 to 1.04
3% dr, average	*million 2012$*	0.04 to 0.14	0.01 to 0.03	0.03 to 0.09	0.56 to 1.85	0.26 to 0.85	0.33 to 1.07	0.01 to 0.03	1.23 to 4.05
2.5% dr, average	*million 2012$*	0.07 to 0.21	0.01 to 0.04	0.04 to 0.13	0.86 to 2.83	0.39 to 1.30	0.50 to 1.64	0.01 to 0.04	1.89 to 6.20
3% dr, 95th perc	*million 2012$*	0.13 to 0.42	0.03 to 0.09	0.08 to 0.26	1.70 to 5.59	0.78 to 2.56	0.99 to 3.24	0.02 to 0.08	3.73 to 12.24
NOx (3% dr)									
At 468 2012$/ton	*million 2012$*	0.008	0.002	0.005	0.102	0.047	0.059	0.001	0.223
At 2,639 2012$/ton	*million 2012$*	0.043	0.009	0.027	0.575	0.263	0.333	0.008	1.259
At 4,809 2012$/ton	*million 2012$*	0.079	0.017	0.049	1.048	0.479	0.607	0.015	2.293
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.002	0.000	0.001	0.032	0.015	0.018	0.000	0.068
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.003	0.001	0.002	0.038	0.018	0.021	0.001	0.082
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.003	0.001	0.002	0.042	0.020	0.024	0.001	0.092
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.004	0.001	0.002	0.055	0.025	0.031	0.001	0.119

Table 10E.1.3 Cumulative and Annualized Benefits and Costs of Considered Standard Levels for CRE Units Shipped in the Period 2017–2046 (TSL 2, 3 Percent Discount Rate)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-Cream Freezers	*Total*
Cumulative Results									
Energy Savings									
Full-Fuel Cycle	*quads*	0.051	0.030	0.009	0.173	0.075	0.081	0.003	0.422
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.054	0.049	0.013	0.146	0.075	0.095	0.006	0.439
Operating Cost Savings	*billion 2012$*	0.317	0.186	0.053	1.023	0.458	0.499	0.020	2.557
NPV	*billion 2012$*	0.263	0.137	0.040	0.877	0.383	0.404	0.014	2.118
Emissions Savings (physical)									
Full-Fuel Cycle									
CO_2	*million metric ton*	2.807	1.640	0.491	9.468	4.130	4.420	0.186	23.142
NOx	*kilo-ton*	4.147	2.422	0.725	13.987	6.101	6.530	0.275	34.187
Hg	*ton*	0.006	0.003	0.001	0.019	0.008	0.009	0.000	0.047
SO_2	*kilo-ton*	3.585	2.094	0.627	12.094	5.275	5.646	0.238	29.561
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	15.742	9.196	2.753	53.099	23.161	24.790	1.046	129.788
3% dr, average	*million 2012$*	76.951	44.952	13.459	259.566	113.220	121.183	5.112	634.442
2.5% dr, average	*million 2012$*	125.394	73.250	21.931	422.968	184.494	197.469	8.330	1033.836
3% dr, 95th perc	*million 2012$*	232.811	135.998	40.719	785.299	342.538	366.629	15.466	1919.460
CO_2 (domestic)									
5% dr, average	*million 2012$*	1.1 to 3.6	0.6 to 2.1	0.2 to 0.6	3.7 to 12.2	1.6 to 5.3	1.7 to 5.7	0.1 to 0.2	9.1 to 29.9
3% dr, average	*million 2012$*	5.4 to 17.7	3.1 to 10.3	0.9 to 3.1	18.2 to 59.7	7.9 to 26.0	8.5 to 27.9	0.4 to 1.2	44.4 to 145.9
2.5% dr, average	*million 2012$*	8.8 to 28.8	5.1 to 16.8	1.5 to 5.0	29.6 to 97.3	12.9 to 42.4	13.8 to 45.4	0.6 to 1.9	72.4 to 237.8
3% dr, 95th perc	*million 2012$*	16.3 to 53.5	9.5 to 31.3	2.9 to 9.4	55.0 to 180.6	24.0 to 78.8	25.7 to 84.3	1.1 to 3.6	134.4 to 441.5
NOx (3% dr)									
At 468 2012$/ton	*million 2012$*	0.977	0.570	0.171	3.294	1.437	1.538	0.065	8.052
At 2,639 2012$/ton	*million 2012$*	5.506	3.216	0.963	18.572	8.101	8.671	0.366	45.395
At 4,809 2012$/ton	*million 2012$*	10.033	5.861	1.755	33.843	14.762	15.800	0.666	82.719
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.279	0.147	0.043	0.934	0.407	0.431	0.015	2.256
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.345	0.185	0.054	1.156	0.504	0.534	0.020	2.798
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.394	0.213	0.063	1.319	0.575	0.611	0.023	3.197
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.506	0.279	0.082	1.697	0.740	0.787	0.030	4.120

Table 10E.1.3 (cont)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-Cream Freezers	Total
Annualized Results									
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.003	0.002	0.001	0.007	0.004	0.005	0.000	0.022
Operating Cost Savings	*billion 2012$*	0.016	0.009	0.003	0.051	0.023	0.025	0.001	0.127
NPV	*billion 2012$*	0.013	0.007	0.002	0.043	0.019	0.020	0.001	0.105
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	0.975	0.570	0.171	3.290	1.435	1.536	0.065	8.041
3% dr, average	*million 2012$*	3.812	2.227	0.667	12.857	5.608	6.003	0.253	31.426
2.5% dr, average	*million 2012$*	5.845	3.414	1.022	19.716	8.600	9.205	0.388	48.190
3% dr, 95th perc	*million 2012$*	11.532	6.736	2.017	38.898	16.967	18.160	0.766	95.077
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.07 to 0.22	0.04 to 0.13	0.01 to 0.04	0.23 to 0.76	0.10 to 0.33	0.11 to 0.35	0.00 to 0.01	0.56 to 1.85
3% dr, average	*million 2012$*	0.27 to 0.88	0.16 to 0.51	0.05 to 0.15	0.90 to 2.96	0.39 to 1.29	0.42 to 1.38	0.02 to 0.06	2.20 to 7.23
2.5% dr, average	*million 2012$*	0.41 to 1.34	0.24 to 0.79	0.07 to 0.24	1.38 to 4.53	0.60 to 1.98	0.64 to 2.12	0.03 to 0.09	3.37 to 11.08
3% dr, 95th perc	*million 2012$*	0.81 to 2.65	0.47 to 1.55	0.14 to 0.46	2.72 to 8.95	1.19 to 3.90	1.27 to 4.18	0.05 to 0.18	6.66 to 21.87
NOx (3% dr)									
At 468 2012$/ton	*million 2012$*	0.048	0.028	0.008	0.163	0.071	0.076	0.003	0.399
At 2,639 2012$/ton	*million 2012$*	0.273	0.159	0.048	0.920	0.401	0.429	0.018	2.249
At 4,809 2012$/ton	*million 2012$*	0.497	0.290	0.087	1.676	0.731	0.783	0.033	4.097
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.014	0.007	0.002	0.047	0.020	0.022	0.001	0.113
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.017	0.009	0.003	0.057	0.025	0.026	0.001	0.139
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.019	0.010	0.003	0.064	0.028	0.030	0.001	0.155
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.025	0.014	0.004	0.084	0.037	0.039	0.002	0.204

Table 10E.1.4 Cumulative and Annualized Benefits and Costs of Considered Standard Levels for CRE Units Shipped in the Period 2017–2046 (TSL 3, 3 Percent Discount Rate)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Cumulative Results									
Energy Savings									
Full-Fuel Cycle	*quads*	0.248	0.141	0.039	0.298	0.082	0.106	0.005	0.920
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.355	0.237	0.083	0.474	0.099	0.139	0.011	1.399
Operating Cost Savings	*billion 2012$*	1.532	0.852	0.232	1.772	0.493	0.657	0.028	5.564
NPV	*billion 2012$*	1.176	0.615	0.148	1.298	0.394	0.518	0.017	4.165
Emissions Savings (physical)									
Full-Fuel Cycle									
CO_2	*million metric ton*	13.612	7.750	2.158	16.339	4.504	5.789	0.255	50.406
NOx	*kilo-ton*	20.108	11.449	3.189	24.136	6.654	8.551	0.376	74.463
Hg	*ton*	0.028	0.016	0.004	0.033	0.009	0.012	0.001	0.103
SO_2	*kilo-ton*	17.387	9.899	2.757	20.870	5.753	7.394	0.325	64.386
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	76.338	43.463	12.105	91.629	25.261	32.463	1.428	282.687
3% dr, average	*million 2012$*	373.163	212.461	59.172	447.914	123.481	158.691	6.979	1381.862
2.5% dr, average	*million 2012$*	608.077	346.210	96.423	729.885	201.216	258.590	11.373	2251.773
3% dr, 95th perc	*million 2012$*	1128.978	642.786	179.022	1355.132	373.584	480.108	21.115	4180.726
CO_2 (domestic)									
5% dr, average	*million 2012$*	5.3 to 17.6	3.0 to 10.0	0.8 to 2.8	6.4 to 21.1	1.8 to 5.8	2.3 to 7.5	0.1 to 0.3	19.8 to 65.0
3% dr, average	*million 2012$*	26.1 to 85.8	14.9 to 48.9	4.1 to 13.6	31.4 to 103.0	8.6 to 28.4	11.1 to 36.5	0.5 to 1.6	96.7 to 317.8
2.5% dr, average	*million 2012$*	42.6 to 139.9	24.2 to 79.6	6.7 to 22.2	51.1 to 167.9	14.1 to 46.3	18.1 to 59.5	0.8 to 2.6	157.6 to 517.9
3% dr, 95th perc	*million 2012$*	79.0 to 259.7	45.0 to 147.8	12.5 to 41.2	94.9 to 311.7	26.2 to 85.9	33.6 to 110.4	1.5 to 4.9	292.7 to 961.6
NOx (3% dr)									
At 468 2012$/ton	*million 2012$*	4.736	2.696	0.751	5.685	1.567	2.014	0.089	17.538
At 2,639 2012$/ton	*million 2012$*	26.700	15.202	4.234	32.048	8.835	11.354	0.499	98.873
At 4,809 2012$/ton	*million 2012$*	48.653	27.701	7.715	58.400	16.100	20.690	0.910	180.169
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	1.258	0.661	0.161	1.395	0.420	0.552	0.018	4.466
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	1.576	0.842	0.212	1.778	0.526	0.688	0.024	5.646
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	1.811	0.976	0.249	2.060	0.604	0.787	0.029	6.516
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	2.354	1.285	0.335	2.712	0.783	1.018	0.039	8.526

Table 10E.1.4 (cont)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	Total
Annualized Results									
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.018	0.012	0.004	0.023	0.005	0.007	0.001	0.069
Operating Cost Savings	*billion 2012$*	0.076	0.042	0.011	0.088	0.024	0.033	0.001	0.276
NPV	*billion 2012$*	0.058	0.030	0.007	0.064	0.019	0.026	0.001	0.206
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	4.729	2.693	0.750	5.677	1.565	2.011	0.088	17.513
3% dr, average	*million 2012$*	18.484	10.524	2.931	22.187	6.116	7.860	0.346	68.448
2.5% dr, average	*million 2012$*	28.344	16.138	4.494	34.022	9.379	12.053	0.530	104.960
3% dr, 95th perc	*million 2012$*	55.922	31.839	8.868	67.124	18.505	23.781	1.046	207.085
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.33 to 1.09	0.19 to 0.62	0.05 to 0.17	0.40 to 1.31	0.11 to 0.36	0.14 to 0.46	0.01 to 0.02	1.23 to 4.03
3% dr, average	*million 2012$*	1.29 to 4.25	0.74 to 2.42	0.21 to 0.67	1.55 to 5.10	0.43 to 1.41	0.55 to 1.81	0.02 to 0.08	4.79 to 15.74
2.5% dr, average	*million 2012$*	1.98 to 6.52	1.13 to 3.71	0.31 to 1.03	2.38 to 7.82	0.66 to 2.16	0.84 to 2.77	0.04 to 0.12	7.35 to 24.14
3% dr, 95th perc	*million 2012$*	3.91 to 12.86	2.23 to 7.32	0.62 to 2.04	4.70 to 15.44	1.30 to 4.26	1.66 to 5.47	0.07 to 0.24	14.50 to 47.63
NOx (3% dr)									
At 468 2012$/ton	*million 2012$*	0.235	0.134	0.037	0.282	0.078	0.100	0.004	0.869
At 2,639 2012$/ton	*million 2012$*	1.323	0.753	0.210	1.587	0.438	0.562	0.025	4.897
At 4,809 2012$/ton	*million 2012$*	2.410	1.372	0.382	2.893	0.797	1.025	0.045	8.924
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.063	0.033	0.008	0.070	0.021	0.028	0.001	0.225
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.078	0.042	0.010	0.088	0.026	0.034	0.001	0.280
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.088	0.047	0.012	0.100	0.029	0.038	0.001	0.316
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.117	0.064	0.017	0.134	0.039	0.050	0.002	0.422

Table 10E.1.5 Cumulative and Annualized Benefits and Costs of Considered Standard Levels for CRE Units Shipped in the Period 2017–2046 (TSL 4, 3 Percent Discount Rate)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Cumulative Results									
Energy Savings									
Full-Fuel Cycle	*quads*	0.254	0.144	0.040	0.360	0.091	0.107	0.005	1.001
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.393	0.261	0.097	0.904	0.138	0.164	0.011	1.967
Operating Cost Savings	*billion 2012$*	1.565	0.870	0.238	2.137	0.530	0.666	0.028	6.034
NPV	*billion 2012$*	1.172	0.608	0.141	1.233	0.392	0.503	0.017	4.067
Emissions Savings (physical)									
Full-Fuel Cycle									
CO_2	*million metric ton*	13.900	7.909	2.214	19.740	4.973	5.887	0.255	54.878
NOx	*kilo-ton*	20.534	11.684	3.271	29.162	7.346	8.697	0.376	81.070
Hg	*ton*	0.028	0.016	0.005	0.040	0.010	0.012	0.001	0.112
SO_2	*kilo-ton*	17.755	10.103	2.829	25.215	6.352	7.520	0.325	70.099
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	77.955	44.356	12.419	110.708	27.888	33.016	1.428	307.769
3% dr, average	*million 2012$*	381.068	216.827	60.706	541.173	136.323	161.394	6.979	1504.471
2.5% dr, average	*million 2012$*	620.958	353.324	98.921	881.853	222.142	262.995	11.373	2451.567
3% dr, 95th perc	*million 2012$*	1152.895	655.995	183.661	1637.282	412.437	488.287	21.115	4551.672
CO_2 (domestic)									
5% dr, average	*million 2012$*	5.5 to 17.9	3.1 to 10.2	0.9 to 2.9	7.7 to 25.5	2.0 to 6.4	2.3 to 7.6	0.1 to 0.3	21.5 to 70.8
3% dr, average	*million 2012$*	26.7 to 87.6	15.2 to 49.9	4.2 to 14.0	37.9 to 124.5	9.5 to 31.4	11.3 to 37.1	0.5 to 1.6	105.3 to 346.0
2.5% dr, average	*million 2012$*	43.5 to 142.8	24.7 to 81.3	6.9 to 22.8	61.7 to 202.8	15.5 to 51.1	18.4 to 60.5	0.8 to 2.6	171.6 to 563.9
3% dr, 95th perc	*million 2012$*	80.7 to 265.2	45.9 to 150.9	12.9 to 42.2	114.6 to 376.6	28.9 to 94.9	34.2 to 112.3	1.5 to 4.9	318.6 to 1046.9
NOx (3% dr)									
At 468 2012$/ton	*million 2012$*	4.836	2.752	0.770	6.868	1.730	2.048	0.089	19.094
At 2,639 2012$/ton	*million 2012$*	27.266	15.514	4.344	38.721	9.754	11.548	0.499	107.645
At 4,809 2012$/ton	*million 2012$*	49.684	28.270	7.915	70.559	17.774	21.043	0.910	196.155
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	1.255	0.655	0.155	1.351	0.422	0.538	0.018	4.394
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	1.580	0.841	0.206	1.813	0.538	0.676	0.024	5.679
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	1.820	0.977	0.245	2.154	0.624	0.777	0.029	6.626
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	2.375	1.293	0.333	2.941	0.822	1.012	0.039	8.815

Table 10E.1.5 (cont)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	Total
Annualized Results									
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.019	0.013	0.005	0.045	0.007	0.008	0.001	0.097
Operating Cost Savings	*billion 2012$*	0.078	0.043	0.012	0.106	0.026	0.033	0.001	0.299
NPV	*billion 2012$*	0.058	0.030	0.007	0.061	0.019	0.025	0.001	0.201
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	4.830	2.748	0.769	6.859	1.728	2.045	0.088	19.067
3% dr, average	*million 2012$*	18.876	10.740	3.007	26.806	6.753	7.994	0.346	74.521
2.5% dr, average	*million 2012$*	28.944	16.469	4.611	41.105	10.355	12.259	0.530	114.273
3% dr, 95th perc	*million 2012$*	57.107	32.494	9.097	81.100	20.429	24.186	1.046	225.459
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.34 to 1.11	0.19 to 0.63	0.05 to 0.18	0.48 to 1.58	0.12 to 0.40	0.14 to 0.47	0.01 to 0.02	1.33 to 4.39
3% dr, average	*million 2012$*	1.32 to 4.34	0.75 to 2.47	0.21 to 0.69	1.88 to 6.17	0.47 to 1.55	0.56 to 1.84	0.02 to 0.08	5.22 to 17.14
2.5% dr, average	*million 2012$*	2.03 to 6.66	1.15 to 3.79	0.32 to 1.06	2.88 to 9.45	0.72 to 2.38	0.86 to 2.82	0.04 to 0.12	8.00 to 26.28
3% dr, 95th perc	*million 2012$*	4.00 to 13.13	2.27 to 7.47	0.64 to 2.09	5.68 to 18.65	1.43 to 4.70	1.69 to 5.56	0.07 to 0.24	15.78 to 51.86
NOx (3% dr)									
At 468 2012$/ton	*million 2012$*	0.240	0.136	0.038	0.340	0.086	0.101	0.004	0.946
At 2,639 2012$/ton	*million 2012$*	1.351	0.768	0.215	1.918	0.483	0.572	0.025	5.332
At 4,809 2012$/ton	*million 2012$*	2.461	1.400	0.392	3.495	0.880	1.042	0.045	9.716
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.063	0.033	0.008	0.068	0.021	0.027	0.001	0.221
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.078	0.042	0.010	0.090	0.027	0.033	0.001	0.281
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.088	0.047	0.012	0.104	0.030	0.038	0.001	0.321
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.118	0.064	0.016	0.146	0.041	0.050	0.002	0.437

Table 10E.1.6 Cumulative and Annualized Benefits and Costs of Considered Standard Levels for CRE Units Shipped in the Period 2017–2046 (TSL 5, 3 Percent Discount Rate)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Cumulative Results									
Energy Savings									
Full-Fuel Cycle	*quads*	0.270	0.162	0.043	0.472	0.165	0.154	0.010	1.278
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	2.322	1.713	0.375	8.039	2.909	3.150	0.219	18.727
Operating Cost Savings	*billion 2012$*	1.669	0.982	0.255	2.834	0.995	0.956	0.064	7.755
NPV	*billion 2012$*	-0.653	-0.731	-0.120	-5.205	-1.914	-2.194	-0.156	-10.972
Emissions Savings (physical)									
Full-Fuel Cycle									
CO_2	*million metric ton*	14.816	8.897	2.359	25.873	9.056	8.438	0.570	70.008
NOx	*kilo-ton*	21.888	13.143	3.484	38.221	13.378	12.464	0.843	103.420
Hg	*ton*	0.030	0.018	0.005	0.053	0.019	0.017	0.001	0.143
SO_2	*kilo-ton*	18.926	11.364	3.013	33.049	11.567	10.778	0.729	89.425
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	83.093	49.893	13.227	145.101	50.786	47.319	3.199	392.618
3% dr, average	*million 2012$*	406.184	243.894	64.657	709.298	248.259	231.312	15.636	1919.241
2.5% dr, average	*million 2012$*	661.885	397.431	105.361	1155.817	404.544	376.927	25.479	3127.443
3% dr, 95th perc	*million 2012$*	1228.881	737.886	195.617	2145.933	751.091	699.817	47.305	5806.529
CO_2 (domestic)									
5% dr, average	*million 2012$*	5.8 to 19.1	3.5 to 11.5	0.9 to 3.0	10.2 to 33.4	3.6 to 11.7	3.3 to 10.9	0.2 to 0.7	27.5 to 90.3
3% dr, average	*million 2012$*	28.4 to 93.4	17.1 to 56.1	4.5 to 14.9	49.7 to 163.1	17.4 to 57.1	16.2 to 53.2	1.1 to 3.6	134.3 to 441.4
2.5% dr, average	*million 2012$*	46.3 to 152.2	27.8 to 91.4	7.4 to 24.2	80.9 to 265.8	28.3 to 93.0	26.4 to 86.7	1.8 to 5.9	218.9 to 719.3
3% dr, 95th perc	*million 2012$*	86.0 to 282.6	51.7 to 169.7	13.7 to 45.0	150.2 to 493.6	52.6 to 172.8	49.0 to 161.0	3.3 to 10.9	406.5 to 1335.5
NOx (3% dr)									
At 468 2012$/ton	*million 2012$*	5.155	3.095	0.821	9.002	3.151	2.936	0.198	24.358
At 2,639 2012$/ton	*million 2012$*	29.063	17.451	4.626	50.751	17.763	16.550	1.119	137.322
At 4,809 2012$/ton	*million 2012$*	52.959	31.799	8.430	92.479	32.368	30.159	2.039	250.233
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	-0.565	-0.678	-0.106	-5.050	-1.860	-2.144	-0.152	-10.555
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	-0.218	-0.470	-0.051	-4.444	-1.648	-1.946	-0.139	-8.916
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.038	-0.316	-0.010	-3.998	-1.492	-1.800	-0.129	-7.708
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.629	0.039	0.084	-2.966	-1.131	-1.464	-0.106	-4.916

Table 10E.1.6 (cont)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Annualized Results									
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.115	0.085	0.019	0.398	0.144	0.156	0.011	0.928
Operating Cost Savings	*billion 2012$*	0.083	0.049	0.013	0.140	0.049	0.047	0.003	0.384
NPV	*billion 2012$*	-0.032	-0.036	-0.006	-0.258	-0.095	-0.109	-0.008	-0.544
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	5.148	3.091	0.819	8.990	3.146	2.932	0.198	24.324
3% dr, average	*million 2012$*	20.120	12.081	3.203	35.134	12.297	11.458	0.774	95.066
2.5% dr, average	*million 2012$*	30.852	18.525	4.911	53.875	18.857	17.569	1.188	145.777
3% dr, 95th perc	*million 2012$*	60.871	36.550	9.690	106.295	37.204	34.664	2.343	287.616
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.36 to 1.18	0.22 to 0.71	0.06 to 0.19	0.63 to 2.07	0.22 to 0.72	0.21 to 0.67	0.01 to 0.05	1.70 to 5.59
3% dr, average	*million 2012$*	1.41 to 4.63	0.85 to 2.78	0.22 to 0.74	2.46 to 8.08	0.86 to 2.83	0.80 to 2.64	0.05 to 0.18	6.65 to 21.87
2.5% dr, average	*million 2012$*	2.16 to 7.10	1.30 to 4.26	0.34 to 1.13	3.77 to 12.39	1.32 to 4.34	1.23 to 4.04	0.08 to 0.27	10.20 to 33.53
3% dr, 95th perc	*million 2012$*	4.26 to 14.00	2.56 to 8.41	0.68 to 2.23	7.44 to 24.45	2.60 to 8.56	2.43 to 7.97	0.16 to 0.54	20.13 to 66.15
NOx (3% dr)									
At 468 2012$/ton	*million 2012$*	0.255	0.153	0.041	0.446	0.156	0.145	0.010	1.207
At 2,639 2012$/ton	*million 2012$*	1.440	0.864	0.229	2.514	0.880	0.820	0.055	6.802
At 4,809 2012$/ton	*million 2012$*	2.623	1.575	0.418	4.581	1.603	1.494	0.101	12.395
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	-0.027	-0.033	-0.005	-0.248	-0.092	-0.106	-0.007	-0.518
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	-0.011	-0.023	-0.003	-0.220	-0.082	-0.096	-0.007	-0.442
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.000	-0.017	-0.001	-0.201	-0.075	-0.090	-0.006	-0.391
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.031	0.002	0.004	-0.147	-0.056	-0.073	-0.005	-0.243

Table 10E.1.7 Cumulative and Annualized Benefits and Costs of Considered Standard Levels for CRE Units Shipped in the Period 2017–2046 (TSL 1, 7 Percent Discount Rate)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Cumulative Results									
Energy Savings									
Full-Fuel Cycle	*quads*	0.008	0.002	0.005	0.108	0.049	0.063	0.002	0.236
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.005	0.001	0.004	0.025	0.010	0.031	0.001	0.077
Operating Cost Savings	*billion 2012$*	0.023	0.005	0.014	0.286	0.133	0.173	0.004	0.638
NPV	*billion 2012$*	0.018	0.004	0.010	0.261	0.122	0.143	0.004	0.561
Emissions Savings (physical)									
Full-Fuel Cycle									
CO_2	*million metric ton*	0.446	0.094	0.278	5.917	2.706	3.429	0.084	12.953
NOx	*kilo-ton*	0.659	0.138	0.410	8.741	3.997	5.066	0.124	19.135
Hg	*ton*	0.001	0.000	0.001	0.012	0.006	0.007	0.000	0.027
SO_2	*kilo-ton*	0.570	0.120	0.355	7.558	3.456	4.380	0.107	16.546
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	2.501	0.525	1.558	33.183	15.175	19.231	0.472	72.644
3% dr, average	*million 2012$*	12.227	2.568	7.615	162.207	74.179	94.005	2.306	355.107
2.5% dr, average	*million 2012$*	19.924	4.184	12.409	264.320	120.876	153.183	3.758	578.655
3% dr, 95th perc	*million 2012$*	36.992	7.768	23.039	490.747	224.423	284.405	6.978	1074.352
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.2 to 0.6	0.0 to 0.1	0.1 to 0.4	2.3 to 7.6	1.1 to 3.5	1.3 to 4.4	0.0 to 0.1	5.1 to 16.7
3% dr, average	*million 2012$*	0.9 to 2.8	0.2 to 0.6	0.5 to 1.8	11.4 to 37.3	5.2 to 17.1	6.6 to 21.6	0.2 to 0.5	24.9 to 81.7
2.5% dr, average	*million 2012$*	1.4 to 4.6	0.3 to 1.0	0.9 to 2.9	18.5 to 60.8	8.5 to 27.8	10.7 to 35.2	0.3 to 0.9	40.5 to 133.1
3% dr, 95th perc	*million 2012$*	2.6 to 8.5	0.5 to 1.8	1.6 to 5.3	34.4 to 112.9	15.7 to 51.6	19.9 to 65.4	0.5 to 1.6	75.2 to 247.1
NOx (7% dr)									
At 468 2012$/ton	*million 2012$*	0.072	0.015	0.045	0.952	0.435	0.552	0.014	2.083
At 2,639 2012$/ton	*million 2012$*	0.404	0.085	0.252	5.365	2.454	3.109	0.076	11.746
At 4,809 2012$/ton	*million 2012$*	0.737	0.155	0.459	9.777	4.471	5.666	0.139	21.404
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.020	0.004	0.012	0.295	0.138	0.162	0.004	0.636
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.030	0.006	0.018	0.428	0.199	0.240	0.006	0.928
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.038	0.008	0.023	0.530	0.246	0.299	0.007	1.151
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.055	0.012	0.034	0.761	0.351	0.433	0.011	1.657

Table 10E.1.7 (cont)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Annualized Results									
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.000	0.000	0.000	0.002	0.001	0.002	0.000	0.006
Operating Cost Savings	*billion 2012$*	0.002	0.000	0.001	0.022	0.010	0.013	0.000	0.048
NPV	*billion 2012$*	0.001	0.000	0.001	0.020	0.009	0.011	0.000	0.042
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	0.155	0.033	0.097	2.056	0.940	1.191	0.029	4.501
3% dr, average	*million 2012$*	0.606	0.127	0.377	8.035	3.674	4.656	0.114	17.590
2.5% dr, average	*million 2012$*	0.929	0.195	0.578	12.321	5.634	7.140	0.175	26.972
3% dr, 95th perc	*million 2012$*	1.832	0.385	1.141	24.308	11.116	14.088	0.346	53.216
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.01 to 0.04	0.00 to 0.01	0.01 to 0.02	0.14 to 0.47	0.07 to 0.22	0.08 to 0.27	0.00 to 0.01	0.32 to 1.04
3% dr, average	*million 2012$*	0.04 to 0.14	0.01 to 0.03	0.03 to 0.09	0.56 to 1.85	0.26 to 0.85	0.33 to 1.07	0.01 to 0.03	1.23 to 4.05
2.5% dr, average	*million 2012$*	0.07 to 0.21	0.01 to 0.04	0.04 to 0.13	0.86 to 2.83	0.39 to 1.30	0.50 to 1.64	0.01 to 0.04	1.89 to 6.20
3% dr, 95th perc	*million 2012$*	0.13 to 0.42	0.03 to 0.09	0.08 to 0.26	1.70 to 5.59	0.78 to 2.56	0.99 to 3.24	0.02 to 0.08	3.73 to 12.24
NOx (7% dr)									
At 468 2012$/ton	*million 2012$*	0.005	0.001	0.003	0.072	0.033	0.042	0.001	0.157
At 2,639 2012$/ton	*million 2012$*	0.030	0.006	0.019	0.404	0.185	0.234	0.006	0.885
At 4,809 2012$/ton	*million 2012$*	0.056	0.012	0.035	0.736	0.337	0.427	0.010	1.612
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.001	0.000	0.001	0.022	0.010	0.012	0.000	0.047
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.002	0.000	0.001	0.028	0.013	0.016	0.000	0.061
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.002	0.000	0.001	0.032	0.015	0.018	0.000	0.070
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.003	0.001	0.002	0.045	0.021	0.025	0.001	0.097

Table 10E.1.8 Cumulative and Annualized Benefits and Costs of Considered Standard Levels for CRE Units Shipped in the Period 2017–2046 (TSL 2, 7 Percent Discount Rate)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Cumulative Results									
Energy Savings									
Full-Fuel Cycle	*quads*	0.051	0.030	0.009	0.173	0.075	0.081	0.003	0.422
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.029	0.027	0.007	0.079	0.041	0.052	0.003	0.238
Operating Cost Savings	*billion 2012$*	0.142	0.083	0.023	0.457	0.205	0.223	0.009	1.143
NPV	*billion 2012$*	0.112	0.057	0.017	0.378	0.164	0.172	0.006	0.905
Emissions Savings (physical)									
Full-Fuel Cycle									
CO_2	*million metric ton*	2.807	1.640	0.491	9.468	4.130	4.420	0.186	23.142
NOx	*kilo-ton*	4.147	2.422	0.725	13.987	6.101	6.530	0.275	34.187
Hg	*ton*	0.006	0.003	0.001	0.019	0.008	0.009	0.000	0.047
SO_2	*kilo-ton*	3.585	2.094	0.627	12.094	5.275	5.646	0.238	29.561
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	15.742	9.196	2.753	53.099	23.161	24.790	1.046	129.788
3% dr, average	*million 2012$*	76.951	44.952	13.459	259.566	113.220	121.183	5.112	634.442
2.5% dr, average	*million 2012$*	125.394	73.250	21.931	422.968	184.494	197.469	8.330	1033.836
3% dr, 95th perc	*million 2012$*	232.811	135.998	40.719	785.299	342.538	366.629	15.466	1919.460
CO_2 (domestic)									
5% dr, average	*million 2012$*	1.1 to 3.6	0.6 to 2.1	0.2 to 0.6	3.7 to 12.2	1.6 to 5.3	1.7 to 5.7	0.1 to 0.2	9.1 to 29.9
3% dr, average	*million 2012$*	5.4 to 17.7	3.1 to 10.3	0.9 to 3.1	18.2 to 59.7	7.9 to 26.0	8.5 to 27.9	0.4 to 1.2	44.4 to 145.9
2.5% dr, average	*million 2012$*	8.8 to 28.8	5.1 to 16.8	1.5 to 5.0	29.6 to 97.3	12.9 to 42.4	13.8 to 45.4	0.6 to 1.9	72.4 to 237.8
3% dr, 95th perc	*million 2012$*	16.3 to 53.5	9.5 to 31.3	2.9 to 9.4	55.0 to 180.6	24.0 to 78.8	25.7 to 84.3	1.1 to 3.6	134.4 to 441.5
NOx (7% dr)									
At 468 2012$/ton	*million 2012$*	0.451	0.264	0.079	1.523	0.664	0.711	0.030	3.722
At 2,639 2012$/ton	*million 2012$*	2.545	1.487	0.445	8.586	3.745	4.008	0.169	20.986
At 4,809 2012$/ton	*million 2012$*	4.638	2.709	0.811	15.645	6.824	7.304	0.308	38.241
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.128	0.066	0.019	0.433	0.188	0.197	0.007	1.038
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.192	0.103	0.030	0.646	0.281	0.297	0.011	1.560
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.240	0.131	0.039	0.810	0.352	0.373	0.014	1.959
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.350	0.195	0.058	1.179	0.513	0.546	0.022	2.862

Table 10E.1.8 (cont)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Annualized Results									
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.002	0.002	0.001	0.006	0.003	0.004	0.000	0.018
Operating Cost Savings	*billion 2012$*	0.011	0.006	0.002	0.034	0.015	0.017	0.001	0.086
NPV	*billion 2012$*	0.008	0.004	0.001	0.028	0.012	0.013	0.000	0.068
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	0.975	0.570	0.171	3.290	1.435	1.536	0.065	8.041
3% dr, average	*million 2012$*	3.812	2.227	0.667	12.857	5.608	6.003	0.253	31.426
2.5% dr, average	*million 2012$*	5.845	3.414	1.022	19.716	8.600	9.205	0.388	48.190
3% dr, 95th perc	*million 2012$*	11.532	6.736	2.017	38.898	16.967	18.160	0.766	95.077
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.07 to 0.22	0.04 to 0.13	0.01 to 0.04	0.23 to 0.76	0.10 to 0.33	0.11 to 0.35	0.00 to 0.01	0.56 to 1.85
3% dr, average	*million 2012$*	0.27 to 0.88	0.16 to 0.51	0.05 to 0.15	0.90 to 2.96	0.39 to 1.29	0.42 to 1.38	0.02 to 0.06	2.20 to 7.23
2.5% dr, average	*million 2012$*	0.41 to 1.34	0.24 to 0.79	0.07 to 0.24	1.38 to 4.53	0.60 to 1.98	0.64 to 2.12	0.03 to 0.09	3.37 to 11.08
3% dr, 95th perc	*million 2012$*	0.81 to 2.65	0.47 to 1.55	0.14 to 0.46	2.72 to 8.95	1.19 to 3.90	1.27 to 4.18	0.05 to 0.18	6.66 to 21.87
NOx (7% dr)									
At 468 2012$/ton	*million 2012$*	0.034	0.020	0.006	0.115	0.050	0.054	0.002	0.280
At 2,639 2012$/ton	*million 2012$*	0.192	0.112	0.034	0.647	0.282	0.302	0.013	1.581
At 4,809 2012$/ton	*million 2012$*	0.349	0.204	0.061	1.178	0.514	0.550	0.023	2.880
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.009	0.005	0.001	0.032	0.014	0.015	0.001	0.076
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.012	0.007	0.002	0.042	0.018	0.019	0.001	0.101
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.014	0.008	0.002	0.049	0.021	0.022	0.001	0.118
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.020	0.011	0.003	0.069	0.030	0.032	0.001	0.166

Table 10E.1.9 Cumulative and Annualized Benefits and Costs of Considered Standard Levels for CRE Units Shipped in the Period 2017–2046 (TSL 3, 7 Percent Discount Rate)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Cumulative Results									
Energy Savings									
Full-Fuel Cycle	*quads*	0.248	0.141	0.039	0.298	0.082	0.106	0.005	0.920
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.204	0.135	0.047	0.257	0.054	0.076	0.006	0.780
Operating Cost Savings	*billion 2012$*	0.684	0.380	0.103	0.792	0.220	0.294	0.013	2.485
NPV	*billion 2012$*	0.480	0.245	0.056	0.534	0.166	0.217	0.006	1.705
Emissions Savings (physical)									
Full-Fuel Cycle									
CO_2	*million metric ton*	13.612	7.750	2.158	16.339	4.504	5.789	0.255	50.406
NOx	*kilo-ton*	20.108	11.449	3.189	24.136	6.654	8.551	0.376	74.463
Hg	*ton*	0.028	0.016	0.004	0.033	0.009	0.012	0.001	0.103
SO_2	*kilo-ton*	17.387	9.899	2.757	20.870	5.753	7.394	0.325	64.386
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	76.338	43.463	12.105	91.629	25.261	32.463	1.428	282.687
3% dr, average	*million 2012$*	373.163	212.461	59.172	447.914	123.481	158.691	6.979	1381.862
2.5% dr, average	*million 2012$*	608.077	346.210	96.423	729.885	201.216	258.590	11.373	2251.773
3% dr, 95th perc	*million 2012$*	1128.978	642.786	179.022	1355.132	373.584	480.108	21.115	4180.726
CO_2 (domestic)									
5% dr, average	*million 2012$*	5.3 to 17.6	3.0 to 10.0	0.8 to 2.8	6.4 to 21.1	1.8 to 5.8	2.3 to 7.5	0.1 to 0.3	19.8 to 65.0
3% dr, average	*million 2012$*	26.1 to 85.8	14.9 to 48.9	4.1 to 13.6	31.4 to 103.0	8.6 to 28.4	11.1 to 36.5	0.5 to 1.6	96.7 to 317.8
2.5% dr, average	*million 2012$*	42.6 to 139.9	24.2 to 79.6	6.7 to 22.2	51.1 to 167.9	14.1 to 46.3	18.1 to 59.5	0.8 to 2.6	157.6 to 517.9
3% dr, 95th perc	*million 2012$*	79.0 to 259.7	45.0 to 147.8	12.5 to 41.2	94.9 to 311.7	26.2 to 85.9	33.6 to 110.4	1.5 to 4.9	292.7 to 961.6
NOx (7% dr)									
At 468 2012$/ton	*million 2012$*	2.189	1.247	0.347	2.628	0.724	0.931	0.041	8.108
At 2,639 2012$/ton	*million 2012$*	12.343	7.028	1.957	14.816	4.084	5.249	0.231	45.709
At 4,809 2012$/ton	*million 2012$*	22.492	12.806	3.567	26.998	7.443	9.565	0.421	83.292
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.558	0.290	0.069	0.628	0.192	0.251	0.008	1.996
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.865	0.464	0.117	0.997	0.294	0.381	0.014	3.133
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	1.100	0.598	0.155	1.279	0.372	0.481	0.018	4.002
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	1.631	0.900	0.239	1.916	0.547	0.707	0.028	5.969

Table 10E.1.9 (cont)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Annualized Results									
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.015	0.010	0.004	0.019	0.004	0.006	0.000	0.059
Operating Cost Savings	*billion 2012$*	0.052	0.029	0.008	0.060	0.017	0.022	0.001	0.187
NPV	*billion 2012$*	0.036	0.018	0.004	0.040	0.013	0.016	0.000	0.128
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	4.729	2.693	0.750	5.677	1.565	2.011	0.088	17.513
3% dr, average	*million 2012$*	18.484	10.524	2.931	22.187	6.116	7.860	0.346	68.448
2.5% dr, average	*million 2012$*	28.344	16.138	4.494	34.022	9.379	12.053	0.530	104.960
3% dr, 95th perc	*million 2012$*	55.922	31.839	8.868	67.124	18.505	23.781	1.046	207.085
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.33 to 1.09	0.19 to 0.62	0.05 to 0.17	0.40 to 1.31	0.11 to 0.36	0.14 to 0.46	0.01 to 0.02	1.23 to 4.03
3% dr, average	*million 2012$*	1.29 to 4.25	0.74 to 2.42	0.21 to 0.67	1.55 to 5.10	0.43 to 1.41	0.55 to 1.81	0.02 to 0.08	4.79 to 15.74
2.5% dr, average	*million 2012$*	1.98 to 6.52	1.13 to 3.71	0.31 to 1.03	2.38 to 7.82	0.66 to 2.16	0.84 to 2.77	0.04 to 0.12	7.35 to 24.14
3% dr, 95th perc	*million 2012$*	3.91 to 12.86	2.23 to 7.32	0.62 to 2.04	4.70 to 15.44	1.30 to 4.26	1.66 to 5.47	0.07 to 0.24	14.50 to 47.63
NOx (7% dr)									
At 468 2012$/ton	*million 2012$*	0.165	0.094	0.026	0.198	0.055	0.070	0.003	0.611
At 2,639 2012$/ton	*million 2012$*	0.930	0.529	0.147	1.116	0.308	0.395	0.017	3.443
At 4,809 2012$/ton	*million 2012$*	1.694	0.964	0.269	2.033	0.561	0.720	0.032	6.273
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.041	0.021	0.005	0.046	0.014	0.018	0.001	0.147
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.056	0.029	0.007	0.064	0.019	0.025	0.001	0.200
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.065	0.035	0.009	0.075	0.022	0.029	0.001	0.237
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.094	0.051	0.013	0.109	0.032	0.041	0.002	0.342

Table 10E.1.10 Cumulative and Annualized Benefits and Costs of Considered Standard Levels for CRE Units Shipped in the Period 2017–2046 (TSL 4, 7 Percent Discount Rate)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Cumulative Results									
Energy Savings									
Full-Fuel Cycle	*quads*	0.254	0.144	0.040	0.360	0.091	0.107	0.005	1.001
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.224	0.148	0.054	0.491	0.075	0.090	0.006	1.089
Operating Cost Savings	*billion 2012$*	0.699	0.388	0.106	0.955	0.237	0.298	0.013	2.695
NPV	*billion 2012$*	0.474	0.240	0.052	0.463	0.162	0.208	0.006	1.606
Emissions Savings (physical)									
Full-Fuel Cycle									
CO_2	*million metric ton*	13.900	7.909	2.214	19.740	4.973	5.887	0.255	54.878
NOx	*kilo-ton*	20.534	11.684	3.271	29.162	7.346	8.697	0.376	81.070
Hg	*ton*	0.028	0.016	0.005	0.040	0.010	0.012	0.001	0.112
SO_2	*kilo-ton*	17.755	10.103	2.829	25.215	6.352	7.520	0.325	70.099
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	77.955	44.356	12.419	110.708	27.888	33.016	1.428	307.769
3% dr, average	*million 2012$*	381.068	216.827	60.706	541.173	136.323	161.394	6.979	1504.471
2.5% dr, average	*million 2012$*	620.958	353.324	98.921	881.853	222.142	262.995	11.373	2451.567
3% dr, 95th perc	*million 2012$*	1152.895	655.995	183.661	1637.282	412.437	488.287	21.115	4551.672
CO_2 (domestic)									
5% dr, average	*million 2012$*	5.5 to 17.9	3.1 to 10.2	0.9 to 2.9	7.7 to 25.5	2.0 to 6.4	2.3 to 7.6	0.1 to 0.3	21.5 to 70.8
3% dr, average	*million 2012$*	26.7 to 87.6	15.2 to 49.9	4.2 to 14.0	37.9 to 124.5	9.5 to 31.4	11.3 to 37.1	0.5 to 1.6	105.3 to 346.0
2.5% dr, average	*million 2012$*	43.5 to 142.8	24.7 to 81.3	6.9 to 22.8	61.7 to 202.8	15.5 to 51.1	18.4 to 60.5	0.8 to 2.6	171.6 to 563.9
3% dr, 95th perc	*million 2012$*	80.7 to 265.2	45.9 to 150.9	12.9 to 42.2	114.6 to 376.6	28.9 to 94.9	34.2 to 112.3	1.5 to 4.9	318.6 to 1046.9
NOx (7% dr)									
At 468 2012$/ton	*million 2012$*	2.236	1.272	0.356	3.175	0.800	0.947	0.041	8.827
At 2,639 2012$/ton	*million 2012$*	12.605	7.172	2.008	17.901	4.509	5.339	0.231	49.764
At 4,809 2012$/ton	*million 2012$*	22.969	13.069	3.659	32.619	8.217	9.728	0.421	90.682
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.554	0.285	0.065	0.577	0.190	0.242	0.008	1.922
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.868	0.464	0.115	1.023	0.303	0.375	0.014	3.160
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	1.108	0.600	0.153	1.363	0.388	0.477	0.018	4.107
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	1.650	0.909	0.239	2.133	0.582	0.706	0.028	6.248

Table 10E.1.10 (cont)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Annualized Results									
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.017	0.011	0.004	0.037	0.006	0.007	0.000	0.082
Operating Cost Savings	*billion 2012$*	0.053	0.029	0.008	0.072	0.018	0.022	0.001	0.203
NPV	*billion 2012$*	0.036	0.018	0.004	0.035	0.012	0.016	0.000	0.121
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	4.830	2.748	0.769	6.859	1.728	2.045	0.088	19.067
3% dr, average	*million 2012$*	18.876	10.740	3.007	26.806	6.753	7.994	0.346	74.521
2.5% dr, average	*million 2012$*	28.944	16.469	4.611	41.105	10.355	12.259	0.530	114.273
3% dr, 95th perc	*million 2012$*	57.107	32.494	9.097	81.100	20.429	24.186	1.046	225.459
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.34 to 1.11	0.19 to 0.63	0.05 to 0.18	0.48 to 1.58	0.12 to 0.40	0.14 to 0.47	0.01 to 0.02	1.33 to 4.39
3% dr, average	*million 2012$*	1.32 to 4.34	0.75 to 2.47	0.21 to 0.69	1.88 to 6.17	0.47 to 1.55	0.56 to 1.84	0.02 to 0.08	5.22 to 17.14
2.5% dr, average	*million 2012$*	2.03 to 6.66	1.15 to 3.79	0.32 to 1.06	2.88 to 9.45	0.72 to 2.38	0.86 to 2.82	0.04 to 0.12	8.00 to 26.28
3% dr, 95th perc	*million 2012$*	4.00 to 13.13	2.27 to 7.47	0.64 to 2.09	5.68 to 18.65	1.43 to 4.70	1.69 to 5.56	0.07 to 0.24	15.78 to 51.86
NOx (7% dr)									
At 468 2012$/ton	*million 2012$*	0.168	0.096	0.027	0.239	0.060	0.071	0.003	0.665
At 2,639 2012$/ton	*million 2012$*	0.949	0.540	0.151	1.348	0.340	0.402	0.017	3.748
At 4,809 2012$/ton	*million 2012$*	1.730	0.984	0.276	2.457	0.619	0.733	0.032	6.830
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	0.041	0.021	0.005	0.042	0.014	0.018	0.001	0.141
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	0.056	0.029	0.007	0.063	0.019	0.024	0.001	0.199
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.066	0.035	0.009	0.077	0.023	0.028	0.001	0.239
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.095	0.052	0.013	0.118	0.033	0.041	0.002	0.353

Table 10E.1.11 Cumulative and Annualized Benefits and Costs of Considered Standard Levels for CRE Units Shipped in the Period 2017–2046 (TSL 5, 7 Percent Discount Rate)

	Units	VOP.RC Equipment	SVO.RC and HZO.RC Equipment	Open Self-Contained Equipment	EPCA Refrigerators and Pull-Down Equipment	EPCA Freezers	VCT.RC and SOC.RC Equipment	Ice-cream Freezers	*Total*
Cumulative Results									
Energy Savings									
Full-Fuel Cycle	*quads*	0.270	0.162	0.043	0.472	0.165	0.154	0.010	1.278
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	1.273	0.937	0.205	4.370	1.581	1.713	0.119	10.200
Operating Cost Savings	*billion 2012$*	0.745	0.438	0.114	1.267	0.445	0.428	0.029	3.465
NPV	*billion 2012$*	-0.528	-0.499	-0.092	-3.103	-1.137	-1.286	-0.091	-6.735
Emissions Savings (physical)									
Full-Fuel Cycle									
CO_2	*million metric ton*	14.816	8.897	2.359	25.873	9.056	8.438	0.570	70.008
NOx	*kilo-ton*	21.888	13.143	3.484	38.221	13.378	12.464	0.843	103.420
Hg	*ton*	0.030	0.018	0.005	0.053	0.019	0.017	0.001	0.143
SO_2	*kilo-ton*	18.926	11.364	3.013	33.049	11.567	10.778	0.729	89.425
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	83.093	49.893	13.227	145.101	50.786	47.319	3.199	392.618
3% dr, average	*million 2012$*	406.184	243.894	64.657	709.298	248.259	231.312	15.636	1919.241
2.5% dr, average	*million 2012$*	661.885	397.431	105.361	1155.817	404.544	376.927	25.479	3127.443
3% dr, 95th perc	*million 2012$*	1228.881	737.886	195.617	2145.933	751.091	699.817	47.305	5806.529
CO_2 (domestic)									
5% dr, average	*million 2012$*	5.8 to 19.1	3.5 to 11.5	0.9 to 3.0	10.2 to 33.4	3.6 to 11.7	3.3 to 10.9	0.2 to 0.7	27.5 to 90.3
3% dr, average	*million 2012$*	28.4 to 93.4	17.1 to 56.1	4.5 to 14.9	49.7 to 163.1	17.4 to 57.1	16.2 to 53.2	1.1 to 3.6	134.3 to 441.4
2.5% dr, average	*million 2012$*	46.3 to 152.2	27.8 to 91.4	7.4 to 24.2	80.9 to 265.8	28.3 to 93.0	26.4 to 86.7	1.8 to 5.9	218.9 to 719.3
3% dr, 95th perc	*million 2012$*	86.0 to 282.6	51.7 to 169.7	13.7 to 45.0	150.2 to 493.6	52.6 to 172.8	49.0 to 161.0	3.3 to 10.9	406.5 to 1335.5
NOx (7% dr)									
At 468 2012$/ton	*million 2012$*	2.383	1.431	0.379	4.162	1.457	1.357	0.092	11.260
At 2,639 2012$/ton	*million 2012$*	13.436	8.067	2.139	23.462	8.212	7.651	0.517	63.484
At 4,809 2012$/ton	*million 2012$*	24.483	14.701	3.897	42.753	14.964	13.942	0.942	115.682
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	-0.442	-0.448	-0.078	-2.954	-1.084	-1.237	-0.087	-6.331
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	-0.108	-0.247	-0.025	-2.370	-0.880	-1.047	-0.075	-4.752
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	0.147	-0.094	0.016	-1.924	-0.724	-0.901	-0.065	-3.544
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.725	0.253	0.108	-0.914	-0.371	-0.572	-0.042	-0.813

Table 10E.1.11 (cont)

	Units	**VOP.RC Equipment**	**SVO.RC and HZO.RC Equipment**	**Open Self-Contained Equipment**	**EPCA Refrigerators and Pull-Down Equipment**	**EPCA Freezers**	**VCT.RC and SOC.RC Equipment**	**Ice-cream Freezers**	***Total***
Annualized Results									
Economic Impacts									
Incremental Equipment Cost	*billion 2012$*	0.096	0.071	0.015	0.329	0.119	0.129	0.009	0.768
Operating Cost Savings	*billion 2012$*	0.056	0.033	0.009	0.095	0.033	0.032	0.002	0.261
NPV	*billion 2012$*	-0.040	-0.038	-0.007	-0.234	-0.086	-0.097	-0.007	-0.507
Emissions Savings (monetized)									
Full-Fuel Cycle									
CO_2 (global)									
5% dr, average	*million 2012$*	5.148	3.091	0.819	8.990	3.146	2.932	0.198	24.324
3% dr, average	*million 2012$*	20.120	12.081	3.203	35.134	12.297	11.458	0.774	95.066
2.5% dr, average	*million 2012$*	30.852	18.525	4.911	53.875	18.857	17.569	1.188	145.777
3% dr, 95th perc	*million 2012$*	60.871	36.550	9.690	106.295	37.204	34.664	2.343	287.616
CO_2 (domestic)									
5% dr, average	*million 2012$*	0.36 to 1.18	0.22 to 0.71	0.06 to 0.19	0.63 to 2.07	0.22 to 0.72	0.21 to 0.67	0.01 to 0.05	1.70 to 5.59
3% dr, average	*million 2012$*	1.41 to 4.63	0.85 to 2.78	0.22 to 0.74	2.46 to 8.08	0.86 to 2.83	0.80 to 2.64	0.05 to 0.18	6.65 to 21.87
2.5% dr, average	*million 2012$*	2.16 to 7.10	1.30 to 4.26	0.34 to 1.13	3.77 to 12.39	1.32 to 4.34	1.23 to 4.04	0.08 to 0.27	10.20 to 33.53
3% dr, 95th perc	*million 2012$*	4.26 to 14.00	2.56 to 8.41	0.68 to 2.23	7.44 to 24.45	2.60 to 8.56	2.43 to 7.97	0.16 to 0.54	20.13 to 66.15
NOx (7% dr)									
At 468 2012$/ton	*million 2012$*	0.179	0.108	0.029	0.313	0.110	0.102	0.007	0.848
At 2,639 2012$/ton	*million 2012$*	1.012	0.608	0.161	1.767	0.618	0.576	0.039	4.781
At 4,809 2012$/ton	*million 2012$*	1.844	1.107	0.294	3.220	1.127	1.050	0.071	8.713
NPV									
Consumer & Emissions Value									
Consumers + CO_2 (1st) + NOx (Low)	*billion 2012$*	-0.034	-0.034	-0.006	-0.224	-0.082	-0.094	-0.007	-0.482
Consumers + CO_2 (2nd) + NOx (Med)	*billion 2012$*	-0.019	-0.025	-0.004	-0.197	-0.073	-0.085	-0.006	-0.407
Consumers + CO_2 (3rd) + NOx (Med)	*billion 2012$*	-0.008	-0.018	-0.002	-0.178	-0.066	-0.079	-0.006	-0.357
Consumers + CO_2 (4th) + NOx (High)	*billion 2012$*	0.023	0.000	0.003	-0.124	-0.047	-0.061	-0.004	-0.211

CHAPTER 11. CUSTOMER SUBGROUP ANALYSIS

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CHAPTER 11. CUSTOMER SUBGROUP ANALYSIS

11.1 INTRODUCTION

The customer subgroup analysis evaluates impacts on identifiable groups of customers of commercial refrigeration equipment who may be disproportionately affected by amended energy conservation standards. The life-cycle cost (LCC) and payback period (PBP) analysis described in chapter 8 of the technical support document (TSD) is applied to seven major types of businesses belonging to the food-retail and foodservice sectors that use a majority of the commercial refrigeration equipment. Although the inputs for different types of businesses are different in the LCC and PBP analysis, the final results may not reflect the results experienced by certain customer subgroups. In other words, some of the adverse impacts on businesses that are disproportionately disadvantaged may be masked by the averaging effect of the LCC and PBP analysis. Therefore, the U.S. Department of Energy (DOE) carried out the customer subgroup analysis by using the LCC and PBP analysis spreadsheet, but applying the inputs that are applicable only to the identified subgroups. The LCC spreadsheet model is accessible at http://www1.eere.energy.gov/buildings/appliance_standards/product.aspx/productid/52.

11.2 IDENTIFYING THE CUSTOMER SUBGROUPS

DOE identified small businesses as a subgroup that could potentially be affected disproportionately by the amended energy conservation standard for commercial refrigeration equipment. DOE was concerned that increases in the purchase price of commercial refrigeration equipment could have negative impacts on small businesses (*i.e.*, those 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 to be small. The SBA established size standards for types of economic activity, or industry, under the North American Industry Classification System (NAICS).[1] Table 11.2.1 presents the size standards established by SBA for various businesses that use commercial refrigeration equipment.

Table 11.2.1 SBA Size Standards for Businesses that Use Commercial Refrigeration Equipment

Business Type	SBA Size Standard Annual Sales *millions*
Supermarkets and Other Grocery (except Convenience) Stores	$30.0
Convenience Stores	$27.0
Meat Markets	$7.0
Fish and Seafood Markets	$7.0
Fruit and Vegetable Markets	$7.0
Baked Goods Stores	$7.0
Confectionery and Nut Stores	$7.0
All Other Specialty Food Stores	$7.0
Beer, Wine and Liquor Stores	$7.0
Gasoline Stations with Convenience Stores	$27.0
Full-Service Restaurants	$7.0
Limited-Service Restaurants	$10.0
Cafeterias, Grill Buffets, and Buffets	$25.5
Snack and Nonalcoholic Beverage Bars	$7.0
Food Service Contractors	$35.5
Caterers	$7.0
Mobile Food Services	$7.0
Drinking Places (Alcoholic Beverages)	$7.0

Source: *Size Standards Used To Define Small Business Concerns* (13 CFR 121.201); also available at http://www.sba.gov/content/table-small-business-size-standards (Last accessed on October 4, 2011).

In examining the businesses that purchase and use commercial refrigeration equipment, DOE analyzed detailed statistical data from the 2007 economic census data.[2] Table 11.2.2, Table 11.2.3, Table 11.2.4, Table 11.2.5 and Table 11.2.6 present the census data for single unit and multiunit firms for five different types of businesses that constitute a dominant share of the commercial refrigeration equipment market.

Table 11.2.2 presents the data for supermarkets and other grocery (except convenience) stores. The data show that 98.9 percent of the firms in this category fall under the SBA definition of small business concerns, and comprise of 66 percent of the total number of establishments, 23 percent of employment, and 18 percent of sales.

Table 11.2.2 Single Unit and Multiunit Firms Census Data for Supermarket and Other Grocery (Except Convenience) Stores

	Description	Number of Firms	Total Employment	Number of Establishments	Sales per Firm *1000$*	Is Average Firm a Small Business?
Supermarkets & other grocery (except convenience) stores*	All firms	41,885	2,432,425	64,881	11,131	Yes
	Single unit firms	39,878	438,104	39,878	1,676	Yes
	Multiunit firms	2,007	1,994,321	25,003	198,998	No
	Firms with 1 establishment	577	18,882	577	4,481	Yes
	Firms with 2 establishments	597	49,967	1,194	11,824	Yes
	Firms with 3 or 4 establishments	374	62,813	1,233	25,250	Yes
	Firms with 5 to 9 establishments	235	87,447	1,514	64,030	No
	Firms with 10 to 24 establishments	128	125,436	1,797	178,695	No
	Firms with 25 to 49 establishments	38	88,107	1,262	422,285	No
	Firms with 50 to 99 establishments	22	133,964	1,533	1,130,223	No
	Firms with 100 establishments or more	36	1,427,705	15,893	8,374,159	No
	Fraction of firms classed as small business		0.989			
	Fraction of establishments that belong to firms classified as small businesses		0.661			
	Fraction of employment in small businesses		0.234			
	Fraction of sales in small businesses		0.184			

*Small business concerns in this category are firms with annual sales less than $30 million.

Table 11.2.3 presents the data for convenience stores. The data show that 99.9 percent of the firms in this category fall under the SBA definition of small business concerns, and comprise of 90 percent of the total number of establishments, 77 percent of employment, and 76 percent of sales.

Table 11.2.3 Single Unit and Multiunit Firms Census Data for Convenience Stores

	Description	Number of Firms	Total Employment	Number of Establishments	Sales per Firm *1000$*	Is Average Firm a Small Business?
Convenience Stores*	All firms	22,168	118,787	25,510	942	Yes
	Single unit firms	21,529	79,302	21,529	661	Yes
	Multiunit firms	639	39,485	3,981	10,408	Yes
	Firms with 1 establishment	300	2,458	300	1,087	Yes
	Firms with 2 establishments	183	2,804	366	2,318	Yes
	Firms with 3 or 4 establishments	86	2,251	281	4,111	Yes
	Firms with 5 to 9 establishments	25	1,014	151	5,843	Yes
	Firms with 10 to 24 establishments	19	3,369	302	23,634	Yes
	Firms with 25 to 49 establishments	12	3,320	443	45,925	No
	Firms with 50 to 99 establishments	10	6,365	694	116,707	No
	Firms with 100 establishments or more	4	17,904	1,444	808,383	No
	Fraction of firms classed as small business		0.999			
	Fraction of establishments that belong to firms classified as small businesses		0.899			
	Fraction of employment in small businesses		0.768			
	Fraction of sales in small businesses		0.763			

*Small business concerns in this category are firms with annual sales less than $27 million.

Table 11.2.4 presents the data for gasoline stations with convenience stores. The data show that 98.8 percent of the firms in this category fall under the SBA definition of small business concerns, and comprise of 60 percent of the total number of establishments, 52 percent of employment, and 43 percent of sales.

Table 11.2.4 Single Unit and Multiunit Firms Census Data for Gasoline Stations with Convenience Stores

	Description	Number of Firms	Total Employment	Number of Establishments	Sales per Firm *1000$*	Is Average Firm a Small Business?
Gasoline Stations with Convenience Stores*	All firms	53,375	719,108	97,508	6,300	Yes
	Single unit firms	49,010	287,220	49,010	2,249	Yes
	Multiunit firms	4,365	431,888	48,498	51,788	No
	Firms with 1 establishment	1,160	11,836	1,160	3,363	Yes
	Firms with 2 establishments	1,168	21,386	2,336	6,622	Yes
	Firms with 3 or 4 establishments	802	24,023	2,697	11,713	Yes
	Firms with 5 to 9 establishments	573	30,488	3,709	22,945	Yes
	Firms with 10 to 24 establishments	402	47,037	5,978	51,678	No
	Firms with 25 to 49 establishments	150	45,235	5,020	128,070	No
	Firms with 50 to 99 establishments	58	31,187	3,865	272,955	No
	Firms with 100 establishments or more	52	220,696	23,733	2,616,567	No
	Fraction of firms classed as small business		0.988			
	Fraction of establishments that belong to firms classified as small businesses		0.604			
	Fraction of employment in small businesses		0.521			
	Fraction of sales in small businesses		0.429			

*Small business concerns in this category are firms with annual sales less than $27 million.

Table 11.2.5 presents the data for full-service restaurants. The data show that 99.5 percent of the firms in this category fall under the SBA definition of small business concerns, and comprise of 87 percent of the total number of establishments, 64 percent of employment, and 65 percent of sales.

Table 11.2.5 Single Unit and Multiunit Firms Census Data for Full-Service Restaurants

	Description	Number of Firms	Total Employment	Number of Establishments	Sales per Firm *1000$*	Is Average Firm a Small Business?
Full-service Restaurants*	All firms	188,758	4,603,747	220,089	1,019	Yes
	Single unit firms	183,759	2,633,075	183,759	614	Yes
	Multiunit firms	4,999	1,970,672	36,330	15,880	No
	Firms with 1 establishment	1,477	57,098	1,477	1,696	Yes
	Firms with 2 establishments	1,762	119,803	3,524	2,797	Yes
	Firms with 3 or 4 establishments	833	115,801	2,796	5,638	Yes
	Firms with 5 to 9 establishments	455	142,324	2,966	12,156	No
	Firms with 10 establishments or more	472	1,535,646	25,567	130,770	No
	Fraction of firms classed as small business		0.995			
	Fraction of establishments that belong to firms classified as small businesses		0.870			
	Fraction of employment in small businesses		0.636			
	Fraction of sales in small businesses		0.650			

*Small business concerns in this category are firms with annual sales less than $7 million.

Table 11.2.6 presents the data for limited-service restaurants. The data show that 99 percent of the firms in this category fall under the SBA definition of small business concerns, and comprise of 73 percent of the total number of establishments, 58 percent of employment, and 58 percent of sales.

Table 11.2.6 Single Unit and Multiunit Firms Census Data for Limited-Service Restaurants

	Description	Number of Firms	Total Employment	Number of Establishments	Sales per Firm *1000$*	Is Average Firm a Small Business?
Limited-service Restaurants*	All firms	136,505	3,384,517	211,313	1,109	Yes
	Single unit firms	126,341	1,263,854	126,341	447	Yes
	Multiunit firms	10,164	2,120,663	84,972	9,331	Yes
	Firms with 1 establishment	1,271	27,674	1,271	981	Yes
	Firms with 2 establishments	2,821	143,768	5,642	2,151	Yes
	Firms with 3 or 4 establishments	2,717	221,095	9,174	3,460	Yes
	Firms with 5 to 9 establishments	1,934	319,625	12,391	7,154	Yes
	Firms with 10 establishments or more	1,421	1,408,501	56,494	45,239	No
	Fraction of firms classed as small business	0.990				
	Fraction of establishments that belong to firms classified as small businesses	0.733				
	Fraction of employment in small businesses	0.584				
	Fraction of sales in small businesses	0.575				

*Small business concerns in this category are firms with annual sales less than $10 million.

The census data clearly show that nearly 99 percent of all the firms in both the food-retail and foodservice sectors fall under the SBA definition of small businesses. Therefore, it can be concluded that in all business types, there are a substantial number of firms that may be disproportionately disadvantaged by the new or amended standards.

In general, the subgroups that face higher cost of capital and lower electricity price rates are more disadvantaged than others. Higher cost of capital imposes burden on the businesses because they have to borrow additional capital to purchase equipment that meets new or amended standards, compared to the case of where there are no new or amended standards. Lower electricity price rates result in lower savings in energy costs and, consequently, lower LCC savings and higher PBPs. Discount rates and average electricity price rates associated with different types of businesses are presented in TSD chapter 8.

In the food-retail sector, small grocery and convenience stores and convenience stores with gas stations face similar discount rates, which are higher than the discount rates for large grocery stores (supermarkets) and multi-line retail stores (supercenters). However, convenience stores with gasoline station face a lower electricity price rate than small grocery and convenience stores. Even though large grocery stores and multi-line retail stores face lower electricity price rates, the far higher discount rates faced by convenience stores and small grocery stores make them likely to be disproportionally disadvantaged.

In the foodservice sector, full-service restaurant face higher discount rates but lower electricity price rates compared to limited-service restaurants. In this case, it is a toss-up between full-service and limited-service restaurants. Full-service restaurants were chosen over limited-service restaurants because a greater share of firms in full-service restaurant category can be classified under the SBA definition of small business concerns (compare data in Table 11.2.5 and Table 11.2.6).

When the full-service restaurants and gasoline stations with convenience stores are compared to one another, full-service restaurants face a far higher discount rate, even though they face slightly lower electricity price rates. However, full-service restaurants use only limited types of commercial refrigeration equipment and some of the large types of equipment such as VOP.RC.M and SOC.RC.M are almost never seen in restaurants. Therefore, DOE identified one subgroup each in the food-retail and foodservice sectors for LCC subgroup analysis. In the food-retail sector, gasoline stations with convenience stores were selected, and in the foodservice sector, full-service restaurant were selected for LCC subgroup analysis.

DOE carried out two LCC subgroup analyses, one each for full-service restaurants and gasoline stations with convenience stores, by using the LCC spreadsheet described in TSD chapter 8, but with certain modifications. The input for business type was fixed to the identified subgroup, which ensured that the discount rates and electricity price rates associated with only that subgroup were selected in the Monte Carlo simulations (see TSD chapter 8). The discount rates for these small businesses were increased by adding the small firm premium to the weighted average cost of capital (see TSD chapter 8 for details). Another major change from the LCC analysis was an added assumption that the subgroups do not have access to national accounts, which results in higher distribution channel markups for the subgroups, leading to higher equipment purchase prices. Apart from these changes, all other inputs for LCC subgroup analysis are same as those in the LCC analysis described in TSD chapter 8.

11.3 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS FOR SMALL BUSINESS SUBGROUPS

Table 11.3.1 presents the comparison of mean LCC savings for the small business subgroup in foodservice sector (full-service restaurants) with the national average values (LCC savings results from TSD chapter 8). The results are presented only for self-contained equipment classes because full-service restaurants that are small businesses generally do not use remote condensing equipment. For all trial standard levels (TSLs) in all equipment classes, the LCC savings for the small business subgroup are lower than the national average values. Table 11.3.2 presents the percentage change in LCC savings compared to national average values. For a majority of equipment classes, the percentage decrease in LCC savings is less than 15 percent. Equipment classes that show a substantial decrease in LCC savings, compared to national average values, are VOP.SC.M, VCT.SC.M, VCT.SC.L, VCT.SC.I, SVO.SC.M, HZO.SC.M, HCT.SC.I, and PD.SC.M, which belong to the classification of self-contained display type equipment. It is uncommon to find display type equipment in small full-service restaurants. An overwhelming majority of commercial refrigeration equipment in small restaurants is comprised of solid door refrigerators and freezers that are used for food storage in the kitchen. The solid-door equipment (VCS and HCS) exhibits relatively smaller percentage decrease in LCC savings. In any case, the value of LCC savings at TSL 4 is positive for all equipment classes. Therefore, even though the LCC savings for small business subgroup in foodservice sector are lower than the national average values, they are still positive, implying that small businesses still save money over the equipment lifetime at TSL 4. Table 11.3.3 presents the comparison of median

PBPs for the small business subgroup in foodservice sector with national median values (median PBPs from TSD chapter 8). The PBP values are higher for the small business subgroup in the majority of cases.

Table 11.3.1 Comparison of Mean LCC Savings for the Small Business Subgroup in the Foodservice Sector with the National Average Values

Equipment Class*	Category	Mean LCC Savings** *2012$*				
		TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.SC.M	Small Business	$157.27	$205.50	$690.22	$576.21	($586.43)
	All Business Types	$170.78	$227.17	$814.91	$691.27	($376.52)
VCT.SC.M	Small Business	$421.59	$960.34	$752.15	$405.47	($954.55)
	All Business Types	$566.18	$1,363.60	$1,122.14	$641.05	($595.52)
VCT.SC.L	Small Business	$3,127.24	$1,879.37	$1,433.25	$941.77	($906.58)
	All Business Types	$4,186.06	$2,522.67	$1,984.45	$1,342.84	($343.16)
VCT.SC.I	Small Business	$414.02	$310.26	$261.24	$261.24	($2,036.01)
	All Business Types	$572.05	$486.28	$431.88	$431.88	($1,591.87)
VCS.SC.M	Small Business	$272.26	$158.67	$125.72	$125.72	($1,079.78)
	All Business Types	$278.84	$162.88	$131.80	$131.80	($1,042.03)
VCS.SC.L	Small Business	$511.64	$318.96	$259.10	$213.08	($1,326.22)
	All Business Types	$524.52	$329.33	$267.81	$220.83	($1,274.03)
VCS.SC.I	Small Business	$231.08	$170.13	$146.54	$146.54	($1,884.22)
	All Business Types	$236.77	$176.83	$152.69	$152.69	($1,818.87)
SVO.SC.M	Small Business	$296.25	$305.21	$486.70	$397.67	($356.12)
	All Business Types	$324.33	$334.89	$587.90	$491.99	($201.61)
HZO.SC.M	Small Business	$8.16	$8.16	$44.26	$18.90	($925.33)
	All Business Types	$8.85	$8.85	$48.60	$28.78	($821.57)
HZO.SC.L†	Small Business	NA	NA	NA	NA	($532.72)
	All Business Types	NA	NA	NA	NA	($473.71)
HCT.SC.M	Small Business	$99.52	$323.44	$274.76	$219.49	($385.92)
	All Business Types	$106.59	$359.48	$307.26	$253.60	($293.54)
HCT.SC.L	Small Business	$209.05	$754.27	$544.14	$344.36	($458.19)
	All Business Types	$217.19	$790.53	$571.07	$368.92	($354.75)
HCT.SC.I	Small Business	$21.15	$32.20	$35.19	$35.19	($926.07)
	All Business Types	$21.83	$34.69	$42.48	$42.48	($811.31)
HCS.SC.M	Small Business	$22.47	$18.59	$16.03	$7.99	($436.55)
	All Business Types	$23.07	$19.18	$16.66	$8.68	($422.79)
HCS.SC.L	Small Business	$72.79	$78.72	$76.67	$76.67	($422.16)
	All Business Types	$74.69	$80.97	$80.72	$80.72	($400.63)
PD.SC.M	Small Business	$815.04	$815.04	$729.72	$187.05	($861.56)
	All Business Types	$1,009.53	$1,009.53	$933.59	$310.43	($637.94)
SOC.SC.M	Small Business	$625.01	$449.27	$1,149.04	$651.93	($959.99)
	All Business Types	$646.15	$466.47	$1,241.60	$739.75	($735.33)

* Only self-contained equipment have been shown for this subgroup analysis because the remote condensing equipment is not generally used by small full-service restaurants.

** Values in parentheses are negative values. Negative percentage values imply decrease in LCC savings and positive percentage values imply increase in LCC savings.

†TSLs 1 through 4 for this equipment class are associated with the baseline efficiency level. Hence, the LCC savings are shown as zero.

Table 11.3.2 Percentage Change in Mean LCC Savings for the Small Business Subgroup in the Foodservice Sector Compared to National Average Values

Equipment Class*	TSL 1**	TSL 2**	TSL 3**	TSL 4**	TSL 5**
VOP.SC.M	(8%)	(10%)	(15%)	(17%)	(56%)
VCT.SC.M	(26%)	(30%)	(33%)	(37%)	(60%)
VCT.SC.L	(25%)	(26%)	(28%)	(30%)	(164%)
VCT.SC.I	(28%)	(36%)	(40%)	(40%)	(28%)
VCS.SC.M	(2%)	(3%)	(5%)	(5%)	(4%)
VCS.SC.L	(2%)	(3%)	(3%)	(4%)	(4%)
VCS.SC.I	(2%)	(4%)	(4%)	(4%)	(4%)
SVO.SC.M	(9%)	(9%)	(17%)	(19%)	(77%)
HZO.SC.M	(8%)	(8%)	(9%)	(34%)	(13%)
HZO.SC.L†	NA	NA	NA	NA	(12%)
HCT.SC.M	(7%)	(10%)	(11%)	(13%)	(31%)
HCT.SC.L	(4%)	(5%)	(5%)	(7%)	(29%)
HCT.SC.I	(3%)	(7%)	(17%)	(17%)	(14%)
HCS.SC.M	(3%)	(3%)	(4%)	(8%)	(3%)
HCS.SC.L	(3%)	(3%)	(5%)	(5%)	(5%)
PD.SC.M	(19%)	(19%)	(22%)	(40%)	(35%)
SOC.SC.M	(3%)	(4%)	(7%)	(12%)	(31%)

* Only self-contained equipment have been shown for this subgroup analysis because the remote condensing equipment is not generally used by small full-service restaurants.
** Values in parentheses are negative values. Negative percentage values imply decrease in LCC savings and positive percentage values imply increase in LCC savings.
† TSLs 1 through 4 for equipment class HZO.SC.L are associated with the baseline efficiency level. Hence, the percentage change in LCC savings are shown as 'NA'.
'0%' means the value is in between -0.5% and 0.5%.

Table 11.3.3 Comparison of Median Payback Periods for the Small Business Subgroup in the Foodservice Sector with National Median Values

Equipment Class	Category	Median Payback Period *years*				
		TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.SC.M	Small Business	1.77	2.38	4.52	4.81	12.46
	All Business Types	1.61	2.17	4.12	4.39	11.37
VCT.SC.M	Small Business	0.89	1.77	2.27	2.61	8.34
	All Business Types	0.86	1.73	2.21	2.54	8.13
VCT.SC.L	Small Business	0.60	0.63	0.85	0.99	3.76
	All Business Types	0.58	0.61	0.83	0.96	3.65
VCT.SC.I	Small Business	0.93	1.89	2.14	2.14	14.34
	All Business Types	0.86	1.74	1.97	1.97	13.21
VCS.SC.M	Small Business	0.74	0.94	1.68	1.68	13.51
	All Business Types	0.78	0.98	1.75	1.75	14.11
VCS.SC.L	Small Business	0.53	0.87	0.96	1.10	10.11
	All Business Types	0.55	0.91	1.00	1.15	10.54
VCS.SC.I	Small Business	0.77	1.99	2.32	2.32	26.08
	All Business Types	0.80	2.07	2.42	2.42	27.19
SVO.SC.M	Small Business	2.15	2.25	4.83	5.17	11.30
	All Business Types	1.97	2.06	4.43	4.75	10.36
HZO.SC.M	Small Business	2.07	2.07	2.64	6.98	60.83
	All Business Types	1.89	1.89	2.42	6.40	55.78
HZO.SC.L*	Small Business	NA	NA	NA	NA	80.27
	All Business Types	NA	NA	NA	NA	73.62

Table 11.3.3 (cont)

Equipment Class	Category	Median Payback Period *years*				
		TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
HCT.SC.M	Small Business	0.77	2.49	2.69	3.43	13.64
	All Business Types	0.69	2.24	2.42	3.08	12.26
HCT.SC.L	Small Business	0.58	1.10	1.15	1.61	7.83
	All Business Types	0.53	1.00	1.05	1.47	7.15
HCT.SC.I	Small Business	0.96	2.60	4.67	4.67	30.57
	All Business Types	0.88	2.39	4.28	4.28	27.99
HCS.SC.M	Small Business	0.48	1.57	2.42	4.06	32.56
	All Business Types	0.50	1.64	2.54	4.28	34.05
HCS.SC.L	Small Business	0.82	1.30	2.47	2.47	14.38
	All Business Types	0.86	1.36	2.57	2.57	14.98
PD.SC.M	Small Business	0.53	0.53	1.11	2.28	7.63
	All Business Types	0.53	0.53	1.10	2.27	7.61
SOC.SC.M	Small Business	1.14	1.26	2.40	3.06	7.59
	All Business Types	1.12	1.24	2.35	2.99	7.42

*TSLs 1 through 4 for this equipment class are associated with the baseline efficiency level. Hence, the PBP is shown as "NA."

Table 11.3.4 presents the comparison of mean LCC savings for the small business subgroup in food-retail sector (convenience stores with gasoline stations) with the national average values (LCC savings results from TSD chapter 8). This comparison shows mixed results with higher LCC savings for the subgroup in some instances and lower in others. The higher LCC savings for the subgroup are exhibited in the case of large remote condensing display cases such as VOP.RC.M, VOP.RC.L, VCT.RC.M, VCT.RC.L, SVO.RC.M, and SOC.RC.M. This equipment is predominantly used in large grocery stores, where the average lifetime of the equipment was assumed to be 10 years, while the average lifetime of this equipment in convenience stores with gas stations was assumed to be 15 years (see TSD chapter 8 for discussion on equipment lifetime assumptions). In general, longer the equipment lifetime, the higher the LCC savings because of a longer available timeframe to offset the initial cost increases by savings in energy costs. Because the large display type equipment is predominantly used in larger grocery and multi-line retail stores, the national average values show lower LCC savings compared to the LCC savings of the subgroup. Self-contained equipment, on the other hand, was assumed to have a 10-year average lifetime in all businesses. Consequently, for self-contained equipment, the subgroup LCC savings were lower than the national average LCC savings.

Table 11.3.5 presents the percentage change in LCC savings of the customer subgroup in the food-retail sector compared to national average values at each TSL. For a majority of equipment classes that show a decrease in LCC savings for the subgroup, the percentage decrease in LCC savings is less than 15 percent. Equipment classes that show a substantial decrease in LCC savings, compared to national average values, are VOP.SC.M, SVO.SC.M, HZO.SC.M, HCT.SC.M, HCT.SC.I, and HCS.SC.M. Among these, the equipment classes that show decrease in LCC savings of greater than 15 percent at TSL 4 are VOP.SC.M (27 percent), SVO.SC.M (26 percent), HZO.SC.M (38 percent), HCT.SC.M (21 percent), HCT.SC.I (17 percent), and HCS.SC.M (15 percent). Even though the percentage decrease in LCC savings for these equipment classes may appear to be high, the absolute value of decrease in LCC savings is small when compared to the total LCC for each equipment class. Table 11.3.6 presents the comparison of median PBPs for small business subgroup in foodservice sector with national median values (median PBPs from TSD chapter 8). The PBP values are higher in the small business subgroup in all instances, including instances in which the LCC savings for the subgroup are higher compared to national average values. This is an expected outcome because the PBP values are obtained by dividing the increase in equipment installed cost by the first year savings in operating costs and are not affected by the higher average lifetime of the equipment in the convenience stores with gas stations.

Table 11.3.4 Comparison of LCC Savings for the Small Business Subgroup in the Food-Retail Sector with the National Average Values

Equipment Class	Category	Mean LCC Savings* *2012$*				
		TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	Small Business	$295.31	$927.25	$2,347.11	$1,970.10	($1,528.98)
	All Business Types	$235.92	$743.00	$1,788.85	$1,493.72	($1,668.79)
VOP.RC.L	Small Business	$668.10	$1,899.69	$1,421.70	$1,421.70	($3,855.19)
	All Business Types	$537.27	$1,516.59	$1,129.51	$1,129.51	($3,692.90)
VOP.SC.M	Small Business	$145.72	$187.71	$608.29	$503.17	($655.21)
	All Business Types	$170.78	$227.17	$814.91	$691.27	($376.52)
VCT.RC.M	Small Business	$205.12	$2,200.61	$2,074.57	$1,313.23	($2,663.30)
	All Business Types	$175.23	$1,864.44	$1,758.73	$1,108.13	($2,508.61)
VCT.RC.L	Small Business	$1,586.15	$1,177.93	$937.97	$937.97	($3,902.43)
	All Business Types	$1,357.25	$1,004.72	$797.91	$797.91	($3,624.20)
VCT.SC.M	Small Business	$535.27	$1,264.79	$1,024.79	$574.38	($784.35)
	All Business Types	$566.18	$1,363.60	$1,122.14	$641.05	($595.52)
VCT.SC.L	Small Business	$3,980.86	$2,396.41	$1,864.97	$1,248.55	($602.09)
	All Business Types	$4,186.06	$2,522.67	$1,984.45	$1,342.84	($343.16)
VCT.SC.I	Small Business	$529.93	$430.30	$375.53	$375.53	($1,881.48)
	All Business Types	$572.05	$486.28	$431.88	$431.88	($1,591.87)
VCS.SC.M	Small Business	$271.17	$157.63	$124.30	$124.30	($1,081.39)
	All Business Types	$278.84	$162.88	$131.80	$131.80	($1,042.03)
VCS.SC.L	Small Business	$510.86	$318.22	$258.09	$211.59	($1,328.25)
	All Business Types	$524.52	$329.33	$267.81	$220.83	($1,274.03)
VCS.SC.I	Small Business	$230.24	$169.16	$145.08	$145.08	($1,886.42)
	All Business Types	$236.77	$176.83	$152.69	$152.69	($1,818.87)
SVO.RC.M	Small Business	$89.01	$674.27	$1,544.54	$1,286.98	($949.64)
	All Business Types	$73.77	$551.98	$1,216.77	$1,008.46	($1,015.16)
SVO.SC.M	Small Business	$285.37	$292.93	$449.78	$364.68	($387.03)
	All Business Types	$324.33	$334.89	$587.90	$491.99	($201.61)
SOC.RC.M	Small Business	$147.25	$280.43	$1,278.84	$670.29	($960.27)
	All Business Types	$118.36	$226.26	$997.89	$494.51	($982.21)
HZO.RC.M**	Small Business	NA	NA	NA	NA	($1,384.63)
	All Business Types	NA	NA	NA	NA	($1,271.24)
HZO.RC.L**	Small Business	NA	NA	NA	NA	($2,306.30)
	All Business Types	NA	NA	NA	NA	($2,134.96)
HZO.SC.M	Small Business	$8.05	$8.05	$43.45	$17.89	($927.01)
	All Business Types	$8.85	$8.85	$48.60	$28.78	($821.57)
HZO.SC.L**	Small Business	NA	NA	NA	NA	($533.60)
	All Business Types	NA	NA	NA	NA	($473.71)
HCT.SC.M	Small Business	$93.73	$299.66	$253.49	$199.55	($407.29)
	All Business Types	$106.59	$359.48	$307.26	$253.60	($293.54)
HCT.SC.L	Small Business	$249.39	$906.61	$655.15	$425.64	($366.23)
	All Business Types	$217.19	$790.53	$571.07	$368.92	($354.75)

Table 11.3.4 (cont)

Equipment Class	Category	Mean LCC Savings *2010$*				
		TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
HCT.SC.I	Small Business	$21.15	$32.20	$35.19	$35.19	($926.07)
	All Business Types	$21.83	$34.69	$42.48	$42.48	($811.31)
HCS.SC.M	Small Business	$22.48	$18.44	$15.75	$7.40	($437.16)
	All Business Types	$23.07	$19.18	$16.66	$8.68	($422.79)
HCS.SC.L	Small Business	$72.46	$78.02	$75.98	$75.98	($423.21)
	All Business Types	$74.69	$80.97	$80.72	$80.72	($400.63)
PD.SC.M	Small Business	$1,026.80	$1,026.80	$945.24	$299.03	($744.27)
	All Business Types	$1,009.53	$1,009.53	$933.59	$310.43	($637.94)
SOC.SC.M	Small Business	$619.20	$444.70	$1,138.70	$643.60	($967.59)
	All Business Types	$646.15	$466.47	$1,241.60	$739.75	($735.33)

* Values in parentheses are negative values.
** TSLs 1 through 4 for equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level. Hence, the LCC savings are shown as 'NA.'

Table 11.3.5 Percentage Change in the Mean LCC Savings for the Small Business Subgroup in the Food-Retail Sector Compared to the National Average Values.

Equipment Class	TSL 1*	TSL 2*	TSL 3*	TSL 4*	TSL 5*
VOP.RC.M	25%	25%	31%	32%	8%
VOP.RC.L	24%	25%	26%	26%	(4%)
VOP.SC.M	(15%)	(17%)	(25%)	(27%)	(74%)
VCT.RC.M	17%	18%	18%	19%	(6%)
VCT.RC.L	17%	17%	18%	18%	(8%)
VCT.SC.M	(5%)	(7%)	(9%)	(10%)	(32%)
VCT.SC.L	(5%)	(5%)	(6%)	(7%)	(75%)
VCT.SC.I	(7%)	(12%)	(13%)	(13%)	(18%)
VCS.SC.M	(3%)	(3%)	(6%)	(6%)	(4%)
VCS.SC.L	(3%)	(3%)	(4%)	(4%)	(4%)
VCS.SC.I	(3%)	(4%)	(5%)	(5%)	(4%)
SVO.RC.M	21%	22%	27%	28%	6%
SVO.SC.M	(12%)	(13%)	(23%)	(26%)	(92%)
SOC.RC.M	24%	24%	28%	36%	2%
HZO.RC.M**	NA	NA	NA	NA	(9%)
HZO.RC.L**	NA	NA	NA	NA	(8%)
HZO.SC.M	(9%)	(9%)	(11%)	(38%)	(13%)
HZO.SC.L**	NA	NA	NA	NA	(13%)
HCT.SC.M	(12%)	(17%)	(17%)	(21%)	(39%)
HCT.SC.L	15%	15%	15%	15%	(3%)
HCT.SC.I	(3%)	(7%)	(17%)	(17%)	(14%)
HCS.SC.M	(3%)	(4%)	(5%)	(15%)	(3%)
HCS.SC.L	(3%)	(4%)	(6%)	(6%)	(6%)
PD.SC.M	2%	2%	1%	(4%)	(17%)
SOC.SC.M	(4%)	(5%)	(8%)	(13%)	(32%)

* Values in parentheses are negative values. Negative percentage values imply decrease in LCC savings and positive percentage values imply increase in LCC savings.
** TSLs 1 through 4 for equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level. Hence, the LCC savings are zero and the decrease in LCC savings are shown as 'NA.'
'0%' means the value is in between -0.5% and 0.5%.

Table 11.3.6 Comparison of Median Payback Periods for the Small Business Subgroup in the Food-Retail Sector with the National Median Values

Equipment Class	Category	Median Payback Period *years*				
		TSL 1	TSL 2	TSL 3	TSL 4	TSL 5
VOP.RC.M	Small Business	1.78	1.83	3.88	4.02	12.09
	All Business Types	1.73	1.77	3.77	3.91	11.76
VOP.RC.L	Small Business	1.15	2.10	2.30	2.30	18.90
	All Business Types	1.11	2.03	2.22	2.22	18.30
VOP.SC.M	Small Business	1.95	2.65	5.02	5.34	13.84
	All Business Types	1.61	2.17	4.12	4.39	11.37
VCT.RC.M	Small Business	1.28	2.51	2.53	2.80	13.61
	All Business Types	1.23	2.42	2.43	2.70	13.09
VCT.RC.L	Small Business	1.35	1.57	1.71	1.71	16.40
	All Business Types	1.30	1.51	1.64	1.64	15.75
VCT.SC.M	Small Business	0.98	1.95	2.49	2.87	9.17
	All Business Types	0.86	1.73	2.21	2.54	8.13
VCT.SC.L	Small Business	0.65	0.68	0.93	1.09	4.12
	All Business Types	0.58	0.61	0.83	0.96	3.65
VCT.SC.I	Small Business	1.02	2.08	2.35	2.35	15.75
	All Business Types	0.86	1.74	1.97	1.97	13.21
VCS.SC.M	Small Business	0.79	1.01	1.79	1.79	14.45
	All Business Types	0.78	0.98	1.75	1.75	14.11
VCS.SC.L	Small Business	0.56	0.93	1.03	1.18	10.80
	All Business Types	0.55	0.91	1.00	1.15	10.54
VCS.SC.I	Small Business	0.82	2.12	2.48	2.48	27.85
	All Business Types	0.80	2.07	2.42	2.42	27.19
SVO.RC.M	Small Business	1.36	2.74	4.49	4.66	12.01
	All Business Types	1.31	2.64	4.34	4.50	11.60
SVO.SC.M	Small Business	2.29	2.40	5.18	5.55	12.12
	All Business Types	1.97	2.06	4.43	4.75	10.36
SOC.RC.M	Small Business	1.28	1.48	3.41	4.54	12.24
	All Business Types	1.25	1.44	3.31	4.41	11.88
HZO.RC.M*	Small Business	NA	NA	NA	NA	166.41
	All Business Types	NA	NA	NA	NA	161.23
HZO.RC.L*	Small Business	NA	NA	NA	NA	86.47
	All Business Types	NA	NA	NA	NA	83.78
HZO.SC.M	Small Business	2.14	2.14	2.74	7.23	62.97
	All Business Types	1.89	1.89	2.42	6.40	55.78
HZO.SC.L*	Small Business	NA	NA	NA	NA	83.02
	All Business Types	NA	NA	NA	NA	73.62
HCT.SC.M	Small Business	0.80	2.60	2.81	3.58	14.23
	All Business Types	0.69	2.24	2.42	3.08	12.26
HCT.SC.L	Small Business	0.59	1.12	1.17	1.65	8.01
	All Business Types	0.53	1.00	1.05	1.47	7.15
HCT.SC.I	Small Business	0.96	2.60	4.67	4.67	30.57
	All Business Types	0.88	2.39	4.28	4.28	27.99
HCS.SC.M	Small Business	0.51	1.68	2.60	4.39	34.88
	All Business Types	0.50	1.64	2.54	4.28	34.05
HCS.SC.L	Small Business	0.88	1.40	2.63	2.63	15.35
	All Business Types	0.86	1.36	2.57	2.57	14.98

Table 11.3.6 (cont)

Equipment Class	Category	Median Payback Period *years*				
		TSL 1	**TSL 2**	**TSL 3**	**TSL 4**	**TSL 5**
PD.SC.M	Small Business	0.58	0.58	1.22	2.50	8.40
	All Business Types	0.53	0.53	1.10	2.27	7.61
SOC.SC.M	Small Business	1.23	1.36	2.58	3.28	8.13
	All Business Types	1.12	1.24	2.35	2.99	7.42

*TSLs 1 through 4 for equipment classes HZO.RC.M, HZO.RC.L and HZO.SC.L are associated with the baseline efficiency level. Hence, the payback period is shown as "NA."

The LCC subgroup analysis results show that the identified subgroups in foodservice and food-retail sector face slightly lower LCC savings and higher PBP values. Comparison of LCC savings values at TSL 4 shows the decrease in LCC savings is less than 15 percent for a majority of the equipment used in small businesses. In all cases at TSL 4, and for both the subgroups, the LCC savings are positive, as are the national average values, indicating that although LCC savings are lower for the customer subgroups, customers still save money over the lifetimes of the equipment. Therefore, DOE concludes that the identified subgroups do not face a substantial disadvantage when compared with an average customer of commercial refrigeration equipment.

REFERENCES

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

12.1 INTRODUCTION

In determining whether a standard is economically justified, the U.S. Department of Energy (DOE or the Department) 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 commercial refrigeration equipment, 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, and 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 commercial refrigeration industry, including data on sales volumes, pricing, employment, and financial structure. In Phase II, "Industry Cash Flow," DOE used the GRIM to assess the potential impacts of amended energy conservation standards on 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 commercial refrigeration industry. Using information from Phase II, DOE refined its analysis in the GRIM, developed additional analyses for subgroups 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 commercial refrigeration industry that built on the market and technology assessment prepared for this rulemaking (refer to chapter 3 of the technical support document (TSD)). Before initiating the detailed impact studies, DOE collected information on the present and past structure and market characteristics of the commercial refrigeration industry. This information included shipments, manufacturer markups, and the cost structures of various manufacturers. The industry profile includes: (1) further detail on the overall market and product characteristics; (2) estimated manufacturer market shares; (3) financial parameters such as net plant, property, and equipment (PPE); selling, general and administrative (SG&A) expenses; cost of goods sold, etc.; and (4) trends in the number of firms, market, and product characteristics. The industry profile included a top-down cost analysis of commercial refrigeration equipment 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] market research tools (*i.e.*, Hoovers[3]), corporate annual reports, and the U.S. Census Bureau's 2011 Annual Survey of Manufacturers.[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 commercial refrigeration equipment. 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 a cash-flow analysis for the commercial refrigeration industry. In performing these analyses, DOE used the financial values derived during Phase I and the shipment scenarios used in the national impact analysis (NIA). In Phase II, DOE performed these preliminary industry cash-flow analyses and prepared written guides for manufacturer interviews.

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 30 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 manufacturer production costs (MPCs), markup assumptions, and shipments forecasts developed in other analyses. DOE derived the manufacturing costs from the engineering analysis and information provided by the industry. It estimated typical manufacturer markups from public financial reports and interviews with manufacturers. DOE developed alternative markup scenarios for the 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 amended energy conservation standards 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. 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) company overview and organizational characteristics; (3) engineering analysis follow-up; (4) manufacturer markups and profitability; (5) shipment projections and market shares; (6) distribution channels; (7) financial parameters; (8) conversion costs; (9) cumulative regulatory burden; (10) direct employment impact assessment; (11) exports, foreign competition, and outsourcing; (12) consolidation; and (13) impacts on small businesses.

12.2.3 Phase III: Subgroup Analysis

For its analysis, DOE presented the impacts on all classes of commercial refrigeration equipment as a whole. While conducting the MIA, DOE interviewed a representative cross-section of commercial refrigeration equipment manufacturers. The MIA interviews broadened the discussion to include business-related topics. DOE sought feedback from industry on the approaches used in the GRIM as well as key issues and concerns. During interviews, DOE defined one manufacturer subgroup, small manufacturers, that could be disproportionately impacted by amended energy conservation standards.

12.2.3.1 Manufacturer Interviews

The information gathered in Phase I and the cash-flow analysis performed in Phase II are supplemented with information gathered from manufacturer interviews in Phase III. The interview process provides an opportunity for interested parties to express their views on important issues privately, allowing confidential or sensitive information to be considered in the rulemaking process.

DOE used these interviews to tailor the GRIM to reflect financial characteristics unique to the commercial refrigeration equipment industry. Interviews were scheduled well in advance to provide every opportunity for key individuals to be available for comment. Although a written response to the questionnaire was acceptable, DOE sought interactive interviews, which help clarify responses and identify additional issues. The resulting information provides valuable inputs to the GRIM 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.

During the interviews, DOE discussed the potential subgroups and subgroup members it identified for the analysis. DOE asked manufacturers and other interested parties to suggest what subgroups or characteristics are the most appropriate to analyze. As described in section 12.2.3, DOE presents the industry impacts on commercial refrigeration equipment manufacturers as a whole because most of the equipment classes represent the same market served by the same manufacturers. However, as discussed below, DOE identified one manufacturer subgroup that warranted a separate impact analysis: small manufacturers.

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 American Heating and Refrigeration Institute (AHRI) and North American Association of Food Equipment Manufacturers (NAFEM)), product databases (*e.g.*, AHRI Directory, NSF International listings, the SBA Database), individual company websites, and market research tools (*e.g.*, Hoovers.com) to create a list of companies that manufacture or sell equipment 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 equipment 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 32 commercial refrigeration equipment manufacturers that are small businesses. DOE made an effort 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, including tooling and investment. The manufacturer interview guides have a series of questions to help identify impacts of amended standards on manufacturing capacity, specifically, capacity utilization and plant location decisions in the United States and North America, with and without amended standards; the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new requirements; the nature and value of any stranded assets; and estimates for any one-time changes to existing 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.

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 commercial refrigeration 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 commercial refrigeration equipment, 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 Enforcement

Interviewed manufacturers expressed concern about the enforcement of an energy efficiency standard for commercial refrigeration equipment. Manufacturers believe that insufficient enforcement will lead to market distortions, as companies that make the necessary investments to meet standards and compliance requirements would be at a distinct pricing disadvantage to unscrupulous competitors that do not fully comply. The manufacturers requested that DOE take the enforcement action necessary to maintain a level playing field and to eliminate non-compliant products from the market.

12.3.2 Certification, Compliance, and Enforcement Costs

Nearly all manufacturers expressed concern over certification, compliance, and enforcement (CC&E) costs. In particular, confusion over the definition of "basic model" and the implementation of alternative efficiency determination methods (AEDMs) has made it difficult for some manufacturers to anticipate their total testing needs and total testing costs.

Manufacturers were concerned that CC&E requirements for commercial refrigeration equipment do not take into account the customized nature of the commercial refrigeration equipment industry. Manufacturers stated that their industry has a high level of end-user specification and low production volumes compared to other industries, such as residential refrigeration. As a result, the strictest interpretations of the CC&E requirements could lead to hundreds of thousands of tests per company. Additional clarification of how basic models and AEDMs apply to the commercial refrigeration equipment industry would help manufacturers understand the testing investments that will be necessary. DOE is aware of the confusion and issued a proposed rulemaking for AEDMs on May 24, 2012 to address these concerns.

12.3.3 Disproportionate Impact on Small Businesses

Manufacturers noted that small businesses will be disproportionately impacted when compared to larger businesses. One manufacturer indicated that small and large manufacturers of the same equipment tend to have similar numbers of basic models, but large manufacturers offer a broader suite of products based on those basic models and have higher sales. Therefore, small manufacturers will be at a disadvantage because they will need to spread both industry certification and conversion costs over a smaller number of shipments.

Also, small manufacturers indicated they have fewer resources to manage CC&E requirements. As a result, they will be forced to focus on compliance rather than innovation. Small manufacturers believe that their large competitors will have greater resources to continue innovating while meeting amended energy conservation standards requirements.

12.3.4 Potential Loss of Product Utility and Decrease in Food Safety

A majority of manufacturers expressed concern about the potential impact of energy conservation standards on product performance. Specifically, manufacturers serving the foodservice industry were concerned about the impacts on food safety, while manufacturers serving the food retail industry were concerned about the impacts on merchandising design.

One manufacturer of commercial refrigeration equipment for the foodservice industry summarized the challenge of amended energy conservation standards as "the design trade-off between product price, energy efficiency, and food safety." In the foodservice industry, refrigeration equipment must maintain safe food temperatures despite frequent door openings in challenging environments, such as kitchens with high temperatures and high humidity. The infiltration of warm, moist air places additional burden on the refrigeration equipment and increases energy usage. Manufacturers were concerned that more-efficient equipment would have trouble maintaining food safety in extreme, but not uncommon, conditions.

Manufacturers in the food retail market design their equipment to optimally present merchandise. Some manufacturers were concerned that energy conservation standards would limit their ability to tailor their commercial refrigeration equipment for specific merchandise. Specifically, manufacturers noted that the highly directional light from light-emitting diode (LED) bulbs could potentially provide lower quality lighting in certain display case applications where the product is presented in multiple layers, such as prepared food display cases. Additionally, manufacturers were concerned that higher efficiency designs could result in less desirable presentation for meats and increased icing on products. In general, more-efficient standards limit manufacturer options for optimizing the presentation features of equipment. Food retail customers such as supermarkets make purchasing decisions based on the various presentation features of commercial refrigeration equipment offered by different manufacturers.

12.4 GRIM INPUTS AND ASSUMPTIONS

The GRIM serves as the main tool for assessing the impacts on industry due to amended energy conservation standards. DOE relies on several sources to obtain inputs for the GRIM. Data and assumptions from these sources are then fed into an accounting model that calculates the industry cash flow both with and without amended energy conservation standards.

12.4.1 Overview of the GRIM

The basic structure of the GRIM, illustrated in Figure 12.4.1, is an annual cash flow analysis that uses manufacturer prices, manufacturing costs, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, 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]

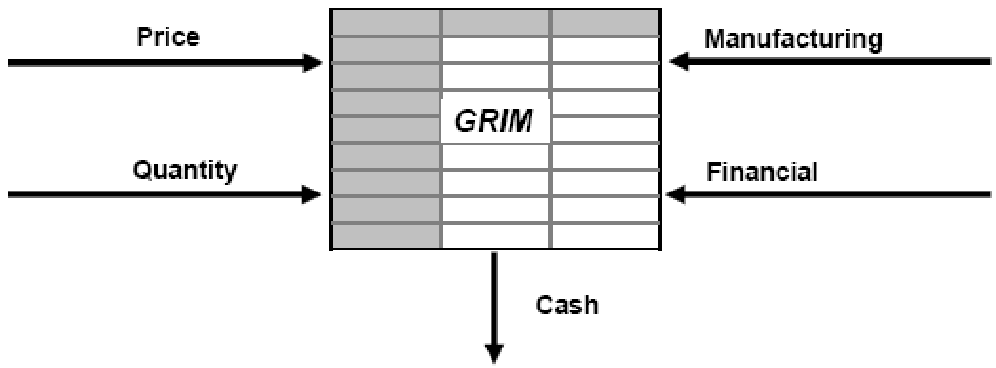

Figure 12.4.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the base-case scenario and the standards-case scenario induced by amended energy conservation standards. The difference in INPV between the base case and the standards case(s) represents the estimated financial impact of the amended energy conservation standard on manufacturers. Appendix 12A provides more technical details and user information for the GRIM.

12.4.2 Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, census data, credit ratings, the shipments model, the engineering analysis, and the manufacturer interviews.

12.4.2.1 Corporate Annual Reports

Corporate annual reports to the SEC (SEC 10-Ks) provided many of the 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 of commercial refrigeration equipment. Since these companies do not provide detailed information about their individual product lines, DOE used the financial information for the entire set of 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's Credit Ratings

S&P provides independent credit ratings, research, and financial information. DOE relied on S&P reports to determine the industry's average cost of debt when calculating the cost of capital.

12.4.2.3 Shipment Model

The GRIM used shipment projections derived from DOE's shipments model in the NIA. Chapter 9 of the TSD describes the methodology and analytical model DOE used to forecast shipments.

12.4.2.4 Engineering Analysis

The engineering analysis establishes the relationship between manufacturer selling price (MSP) and energy efficiency for the equipment covered in this rulemaking. DOE adopted a design option approach to develop cost-efficiency curves in its engineering analysis. DOE began its analysis by conducting industry research to select equipment classes to directly analyze, develop baseline unit specifications, and select representative commercial refrigeration equipment for further analysis. Next, DOE determined efficiency levels based on the design options applicable to the specific equipment studied and the maximum technologically feasible efficiency level for each equipment class modeled. To develop cost estimates, DOE conducted a price analysis, based upon physical teardowns of selected units, cost estimates from publicly available sources, and price quotes from manufacturers. DOE then developed a cost model to determine MPCs. By applying derived manufacturer markups to the MPC, DOE calculated the MSP and constructed industry cost-efficiency curves. See chapter 5 of the TSD for a complete discussion of the engineering analysis.

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 commercial refrigeration equipment. The values listed are averages over a 7-year period (2004 to 2010).

Table 12.4.1 GRIM Financial Parameters Based on 2004–2010 Weighted Company Financial Data

Parameter	Industry-Weighted Average	Manufacturers						
		A	B	C	D	E	F	G
Tax Rate (% of Taxable Income)	25%	27.3%	21.4%	34.3%	16.2%	31.5%	30.3%	25.8%
Working Capital (% of Revenue)	9.2%	8.1%	22.4%	10.1%	-7.9%	16.6%	10%	16.2%
SG&A (% of Revenue)	13.1%	11.5%	11.1%	19.3%	15.2%	23.1%	15.3%	5.1%
R&D (% of Revenues)	1.6%	3.1%	1.1%	1.3%	1.6%	0.5%	1.9%	0.6%
Depreciation (% of Revenues)	2%	2.3%	2.1%	1.4%	2.5%	2.3%	2.9%	0.6%
Capital Expenditures (% of Revenues)	1.7%	1.9%	1.9%	1.8%	1.6%	1.5%	2.8%	0.5%

While most of these companies also manufacture 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 12.4.1. Where applicable, DOE adjusted the parameters in the GRIM using manufacturer feedback and market share information.

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 commercial refrigeration equipment industry based on several representative companies, using the following formula:

$$WACC = \textit{After-Tax Cost of Debt} \times (\textit{Debt Ratio}) + \textit{Cost of Equity} \times (\textit{Equity Ratio})$$

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:

$$\textit{Cost of Equity} = \textit{Riskless Rate of Return} + \beta \times \textit{Risk Premium}$$

Where:

Riskless Rate of Return = the rate of return on a "safe" benchmark investment, typically considered the short-term Treasury Bill (T-Bill) yield,
Risk Premium = the difference between the expected return on stocks and the riskless rate, and
Beta (β) = the correlation between the movement in the price of the stock and that of the broader market. In this case, Beta equals one if the stock is perfectly correlated with the S&P 500 market index. A Beta lower than one means the stock is less volatile than the market index.

DOE calculated that the industry average cost of equity for the commercial refrigeration industry is 14.7 percent (Table 12.4.2).

Table 12.4.2 Cost of Equity Calculation

Parameter	Industry-Weighted Average	A	B	C	D	E	F	G
(1) Average Beta	1.55	1.30	2.70	0.76	1.77	0.91	1.29	1.29
(2) Yield on 10-Year (1928-2010)	5.23%							
(3) Market Risk Premium	6.09%							
Cost of Equity (2)+[(1)*(3)]	14.7%							
Equity/Total Capital	61.9%	69.0%	19.8%	65.0%	73.4%	67.3%	71.0%	71.7%

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 seven 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 seven manufacturers 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 12.4.3 presents the derivation of the cost of debt and the capital structure of the industry (*i.e.*, the debt ratio (debt/total capital)).

Table 12.4.3 Cost of Debt Calculation

Parameter	Industry-Weighted Average	A	B	C	D	E	F	G
S&P Bond Rating		AAA	CC	AAA	A	AAA	AAA	AAA
(1) Yield on 10-Year (1928-2010)	5.23%							
(2) Gross Cost of Debt	6.9%	6.23%	8.98%	6.83%	6.83%	5.73%	6.83%	6.23%
(3) Tax Rate	25%	27.3%	21.4%	34.3%	16.2%	31.5%	30.3%	25.8%
Net Cost of Debt (2) x [1-(3)]	5.2%							
Debt/Total Capital	38.1%	31.0%	80.2%	35.0%	26.6%	32.7%	29.0%	28.3%

Using public information for these seven companies, the initial estimate for the industry's WACC was approximately 11.1 percent. Subtracting an inflation rate of 3.09 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 percent. DOE also asked for feedback on the discount rate during manufacturer interviews. Based on this feedback, DOE used a discount rate of 10 percent for the commercial refrigeration industry.

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. Table 12.4.4 presents the TSLs used for energy efficiency analysis in the GRIM.

Table 12.4.4 Trial Standard Levels for Energy Efficiency Analysis of Commercial Refrigeration Equipment

Equipment Class						
	Baseline	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**
VOP.RC.M	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
VOP.RC.L	Level 1	Level 2	Level 3	Level 4	Level 4	Level 5
VOP.SC.M	Level 1	Level 3	Level 4	Level 5	Level 6	Level 7
VCT.RC.M	Level 1	Level 2	Level 3	Level 4	Level 6	Level 7
VCT.RC.L	Level 1	Level 3	Level 4	Level 5	Level 5	Level 6
VCT.SC.M	Level 1	Level 2	Level 3	Level 4	Level 7	Level 8
VCT.SC.L	Level 1	Level 3	Level 4	Level 5	Level 7	Level 8
VCT.SC.I	Level 1	Level 3	Level 5	Level 6	Level 6	Level 7
VCS.SC.M	Level 1	Level 3	Level 5	Level 7	Level 7	Level 8
VCS.SC.L	Level 1	Level 3	Level 5	Level 6	Level 7	Level 8
VCS.SC.I	Level 1	Level 3	Level 5	Level 6	Level 6	Level 7
SVO.RC.M	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
SVO.SC.M	Level 1	Level 3	Level 4	Level 5	Level 6	Level 7
SOC.RC.M	Level 1	Level 2	Level 3	Level 4	Level 6	Level 7
HZO.RC.M	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
HZO.RC.L	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
HZO.SC.M	Level 1	Level 2	Level 2	Level 3	Level 4	Level 5
HZO.SC.L	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
HCT.SC.M	Level 1	Level 3	Level 5	Level 6	Level 7	Level 8
HCT.SC.L	Level 1	Level 3	Level 4	Level 5	Level 7	Level 8
HCT.SC.I	Level 1	Level 2	Level 3	Level 4	Level 4	Level 5
HCS.SC.M	Level 1	Level 2	Level 3	Level 4	Level 5	Level 7
HCS.SC.L	Level 1	Level 4	Level 5	Level 6	Level 6	Level 7
PD.SC.M	Level 1	Level 2	Level 2	Level 3	Level 7	Level 8
SOC.SC.M	Level 1	Level 3	Level 4	Level 5	Level 7	Level 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 of the shipped units for a given standards case are a key driver of manufacturer finances. For this analysis, the GRIM applied the NIA shipments forecasts.

As part of the shipments analysis, DOE estimated the base-case shipment distribution by efficiency level for each equipment class. In the standards case, DOE determined efficiency distributions for cases in which a potential standard applies for 2017 and beyond. DOE assumed that all shipments in the base case that did not meet the standard under consideration would meet the new standard in 2017 under a roll-up scenario. Customers in the base case who purchase units above the standard level are not affected as they are assumed to continue to purchase the same base-case unit in the standards case.

See chapter 9 of the TSD for more information on the commercial refrigeration equipment standards-case shipments.

12.4.7 Manufacturer 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 MPCs derived in the engineering analysis.

Manufacturing a higher efficiency product is typically more expensive than manufacturing a baseline product. MPCs increase at higher efficiency levels due to the use of more complex components, which are more costly than baseline components. These changes in MPCs can affect the revenues, gross margins, and cash flow of the industry, making these product cost data key GRIM inputs for DOE's analysis.

To calculate baseline MSP, DOE followed a three-step process. First, DOE derived MPCs from the engineering and teardown analyses. Second, DOE applied a manufacturer markup, which varies with the markup scenario (discussed in detail in section 12.4.9), to the MPCs. Third, shipping costs from the engineering analysis were added to the marked-up MPCs.

Table 12.4.5 through Table 12.4.29 show the production cost estimates used in the GRIM for each analyzed equipment class.

Table 12.4.5 Manufacturer Production Cost Breakdown (2012$) for VOP.RC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$2,620.53	$510.43	$102.60	$139.14	$3,372.71	$252.30	1.42	$5,041.54
EL 2	$2,652.21	$510.43	$102.60	$139.14	$3,404.38	$252.30	1.42	$5,086.52
EL 3	$2,738.26	$510.43	$102.60	$139.14	$3,490.44	$252.30	1.42	$5,208.72
EL 4	$3,455.00	$510.43	$102.60	$139.14	$4,207.18	$252.30	1.42	$6,226.49
EL 5	$3,500.13	$510.43	$102.60	$139.14	$4,252.31	$252.30	1.42	$6,290.57
EL 6	$5,336.12	$545.61	$102.60	$139.14	$6,123.48	$252.30	1.42	$8,947.63

Table 12.4.6 Manufacturer Production Cost Breakdown (2012$) for VOP.RC.L

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$2,913.14	$510.45	$102.60	$139.70	$3,665.89	$252.30	1.42	$5,457.86
EL 2	$2,956.38	$510.45	$102.60	$139.70	$3,709.13	$252.30	1.42	$5,519.26
EL 3	$3,204.69	$510.45	$102.60	$139.70	$3,957.44	$252.30	1.42	$5,871.86
EL 4	$3,254.74	$510.45	$102.60	$139.70	$4,007.48	$252.30	1.42	$5,942.92
EL 5	$6,266.11	$553.25	$102.60	$139.70	$7,061.66	$252.30	1.42	$10,279.86

Table 12.4.7 Manufacturer Production Cost Breakdown (2012$) for VOP.SC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$1,496.08	$197.23	$57.09	$65.64	$1,816.05	$68.90	1.42	$2,647.69
EL 2	$1,506.99	$197.23	$57.09	$65.64	$1,826.96	$68.90	1.42	$2,663.18
EL 3	$1,519.40	$197.23	$57.09	$65.64	$1,839.37	$68.90	1.42	$2,680.80
EL 4	$1,545.77	$197.23	$57.09	$65.64	$1,865.74	$68.90	1.42	$2,718.25
EL 5	$1,840.69	$197.23	$57.09	$65.64	$2,160.66	$68.90	1.42	$3,137.04
EL 6	$1,870.96	$197.23	$57.09	$65.64	$2,190.93	$68.90	1.42	$3,180.03
EL 7	$2,496.96	$209.43	$57.09	$65.64	$2,829.13	$68.90	1.42	$4,086.26

Table 12.4.8 Manufacturer Production Cost Breakdown (2012$) for VCT.RC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$3,842.91	$589.50	$111.60	$138.04	$4,682.04	$235.07	1.42	$6,883.57
EL 2	$3,857.78	$589.50	$111.60	$138.04	$4,696.91	$235.07	1.42	$6,904.68
EL 3	$4,218.63	$589.50	$111.60	$138.04	$5,057.76	$235.07	1.42	$7,417.09
EL 4	$4,309.11	$589.50	$111.60	$138.04	$5,148.24	$235.07	1.42	$7,545.57
EL 5	$4,357.86	$589.50	$111.60	$138.04	$5,196.99	$235.07	1.42	$7,614.80
EL 6	$4,374.96	$589.50	$111.60	$138.04	$5,214.09	$235.07	1.42	$7,639.08
EL 7	$6,506.53	$630.30	$111.60	$138.04	$7,386.46	$235.07	1.42	$10,723.85

Table 12.4.9 Manufacturer Production Cost Breakdown (2012$) for VCT.RC.L

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$4,525.20	$589.64	$111.60	$140.89	$5,367.33	$235.07	1.42	$7,856.68
EL 2	$4,635.35	$589.64	$111.60	$140.89	$5,477.48	$235.07	1.42	$8,013.09
EL 3	$4,725.84	$589.64	$111.60	$140.89	$5,567.96	$235.07	1.42	$8,141.58
EL 4	$4,774.07	$589.64	$111.60	$140.89	$5,616.20	$235.07	1.42	$8,210.08
EL 5	$4,804.51	$589.64	$111.60	$140.89	$5,646.64	$235.07	1.42	$8,253.30
EL 6	$7,617.82	$629.64	$111.60	$140.89	$8,499.95	$235.07	1.42	$12,305.00

Table 12.4.10 Manufacturer Production Cost Breakdown (2012$) for VCT.SC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$1,421.52	$190.33	$104.04	$72.72	$1,788.61	$61.81	1.42	$2,601.63
EL 2	$1,450.36	$190.33	$104.04	$72.72	$1,817.45	$61.81	1.42	$2,642.59
EL 3	$1,604.00	$190.33	$104.04	$72.72	$1,971.10	$61.81	1.42	$2,860.76
EL 4	$1,694.48	$190.33	$104.04	$72.72	$2,061.58	$61.81	1.42	$2,989.25
EL 5	$1,709.48	$190.33	$104.04	$72.72	$2,076.57	$61.81	1.42	$3,010.54
EL 6	$1,741.30	$190.33	$104.04	$72.72	$2,108.40	$61.81	1.42	$3,055.73
EL 7	$1,748.20	$190.33	$104.04	$72.72	$2,115.29	$61.81	1.42	$3,065.52
EL 8	$2,500.75	$204.93	$104.04	$72.72	$2,882.44	$61.81	1.42	$4,154.88

Table 12.4.11 Manufacturer Production Cost Breakdown (2012$) for VCT.SC.L

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$2,044.03	$216.14	$69.21	$69.83	$2,399.20	$61.81	1.42	$3,468.67
EL 2	$2,096.67	$216.14	$69.21	$69.83	$2,451.85	$61.81	1.42	$3,543.43
EL 3	$2,241.15	$216.14	$69.21	$69.83	$2,596.32	$61.81	1.42	$3,748.59
EL 4	$2,253.06	$216.14	$69.21	$69.83	$2,608.23	$61.81	1.42	$3,765.49
EL 5	$2,343.54	$216.14	$69.21	$69.83	$2,698.71	$61.81	1.42	$3,893.98
EL 6	$2,352.85	$216.14	$69.21	$69.83	$2,708.02	$61.81	1.42	$3,907.19
EL 7	$2,399.66	$216.14	$69.21	$69.83	$2,754.84	$61.81	1.42	$3,973.68
EL 8	$3,416.49	$230.74	$69.21	$69.83	$3,786.27	$61.81	1.42	$5,438.31

Table 12.4.12 Manufacturer Production Cost Breakdown (2012$) for VCT.SC.I

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$2,293.43	$215.88	$69.21	$70.65	$2,649.17	$64.85	1.42	$3,826.67
EL 2	$2,346.13	$215.88	$69.21	$70.65	$2,701.87	$64.85	1.42	$3,901.50
EL 3	$2,355.44	$215.88	$69.21	$70.65	$2,711.17	$64.85	1.42	$3,914.72
EL 4	$2,445.92	$215.88	$69.21	$70.65	$2,801.66	$64.85	1.42	$4,043.20
EL 5	$2,460.91	$215.88	$69.21	$70.65	$2,816.65	$64.85	1.42	$4,064.49
EL 6	$2,493.25	$215.88	$69.21	$70.65	$2,848.99	$64.85	1.42	$4,110.41
EL 7	$3,845.07	$231.28	$69.21	$70.65	$4,216.21	$64.85	1.42	$6,051.86

Table 12.4.13 Manufacturer Production Cost Breakdown (2012$) for VCS.SC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$729.30	$216.69	$121.26	$83.07	$1,150.32	$60.79	1.42	$1,694.25
EL 2	$757.39	$216.69	$121.26	$83.07	$1,178.41	$60.79	1.42	$1,734.13
EL 3	$761.47	$216.69	$121.26	$83.07	$1,182.49	$60.79	1.42	$1,739.93
EL 4	$764.30	$216.69	$121.26	$83.07	$1,185.31	$60.79	1.42	$1,743.94
EL 5	$773.60	$216.69	$121.26	$83.07	$1,194.62	$60.79	1.42	$1,757.16
EL 6	$788.60	$216.69	$121.26	$83.07	$1,209.61	$60.79	1.42	$1,778.45
EL 7	$820.42	$216.69	$121.26	$83.07	$1,241.44	$60.79	1.42	$1,823.64
EL 8	$1,572.97	$231.29	$121.26	$83.07	$2,008.59	$60.79	1.42	$2,912.99

Table 12.4.14 Manufacturer Production Cost Breakdown (2012$) for VCS.SC.L

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$859.57	$216.70	$121.26	$83.68	$1,281.21	$60.79	1.42	$1,880.11
EL 2	$892.47	$216.70	$121.26	$83.68	$1,314.12	$60.79	1.42	$1,926.84
EL 3	$901.42	$216.70	$121.26	$83.68	$1,323.06	$60.79	1.42	$1,939.54
EL 4	$906.69	$216.70	$121.26	$83.68	$1,328.33	$60.79	1.42	$1,947.02
EL 5	$938.51	$216.70	$121.26	$83.68	$1,360.15	$60.79	1.42	$1,992.21
EL 6	$947.82	$216.70	$121.26	$83.68	$1,369.46	$60.79	1.42	$2,005.42
EL 7	$962.81	$216.70	$121.26	$83.68	$1,384.45	$60.79	1.42	$2,026.71
EL 8	$1,979.64	$231.30	$121.26	$83.68	$2,415.88	$60.79	1.42	$3,491.34

Table 12.4.15 Manufacturer Production Cost Breakdown (2012$) for VCS.SC.I

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$1,105.52	$216.95	$121.26	$86.48	$1,530.21	$64.85	1.42	$2,237.75
EL 2	$1,105.84	$216.95	$121.26	$86.48	$1,530.53	$64.85	1.42	$2,238.20
EL 3	$1,119.90	$216.95	$121.26	$86.48	$1,544.60	$64.85	1.42	$2,258.17
EL 4	$1,129.21	$216.95	$121.26	$86.48	$1,553.90	$64.85	1.42	$2,271.39
EL 5	$1,161.55	$216.95	$121.26	$86.48	$1,586.24	$64.85	1.42	$2,317.31
EL 6	$1,176.54	$216.95	$121.26	$86.48	$1,601.24	$64.85	1.42	$2,338.60
EL 7	$2,528.36	$232.35	$121.26	$86.48	$2,968.45	$64.85	1.42	$4,280.05

Table 12.4.16 Manufacturer Production Cost Breakdown (2012$) for SVO.RC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$2,215.79	$476.62	$87.89	$120.46	$2,900.76	$139.83	1.42	$4,258.91
EL 2	$2,222.72	$476.62	$87.89	$120.46	$2,907.69	$139.83	1.42	$4,268.75
EL 3	$2,346.81	$476.62	$87.89	$120.46	$3,031.78	$139.83	1.42	$4,444.96
EL 4	$2,893.83	$476.62	$87.89	$120.46	$3,578.80	$139.83	1.42	$5,221.73
EL 5	$2,930.88	$476.62	$87.89	$120.46	$3,615.85	$139.83	1.42	$5,274.33
EL 6	$4,108.57	$499.30	$87.89	$120.46	$4,816.22	$139.83	1.42	$6,978.85

Table 12.4.17 Manufacturer Production Cost Breakdown (2012$) for SVO.SC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$1,167.10	$156.74	$55.37	$58.74	$1,437.95	$42.56	1.42	$2,084.45
EL 2	$1,168.74	$156.74	$55.37	$58.74	$1,439.59	$42.56	1.42	$2,086.78
EL 3	$1,210.10	$156.74	$55.37	$58.74	$1,480.96	$42.56	1.42	$2,145.51
EL 4	$1,227.68	$156.74	$55.37	$58.74	$1,498.54	$42.56	1.42	$2,170.48
EL 5	$1,468.19	$156.74	$55.37	$58.74	$1,739.04	$42.56	1.42	$2,512.00
EL 6	$1,495.77	$156.74	$55.37	$58.74	$1,766.62	$42.56	1.42	$2,551.16
EL 7	$1,822.77	$244.78	$55.37	$58.74	$2,181.67	$42.56	1.42	$3,140.52

Table 12.4.18 Manufacturer Production Cost Breakdown (2012$) for SOC.RC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$4,189.91	$600.96	$96.63	$193.59	$5,081.10	$165.16	1.42	$7,380.32
EL 2	$4,200.61	$600.96	$96.63	$193.59	$5,091.80	$165.16	1.42	$7,395.51
EL 3	$4,220.23	$600.96	$96.63	$193.59	$5,111.42	$165.16	1.42	$7,423.38
EL 4	$4,547.77	$600.96	$96.63	$193.59	$5,438.96	$165.16	1.42	$7,888.48
EL 5	$4,581.09	$600.96	$96.63	$193.59	$5,472.28	$165.16	1.42	$7,935.80
EL 6	$4,684.50	$600.96	$96.63	$193.59	$5,575.69	$165.16	1.42	$8,082.64
EL 7	$5,558.96	$617.88	$96.63	$193.59	$6,467.08	$165.16	1.42	$9,348.41

Table 12.4.19 Manufacturer Production Cost Breakdown (2012$) for HZO.RC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$2,221.78	$371.95	$75.48	$113.94	$2,783.15	$113.48	1.42	$4,065.56
EL 2	$3,016.08	$390.61	$75.48	$113.94	$3,596.11	$113.48	1.42	$5,219.96

Table 12.4.20 Manufacturer Production Cost Breakdown (2012$) for HZO.RC.L

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$2,639.12	$371.89	$75.48	$114.18	$3,200.67	$113.48	1.42	$4,658.43
EL 2	$4,059.52	$399.89	$75.48	$114.18	$4,649.07	$113.48	1.42	$6,715.17

Table 12.4.21 Manufacturer Production Cost Breakdown (2012$) for HZO.SC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$588.56	$76.15	$30.78	$26.06	$721.56	$20.26	1.42	$1,044.88
EL 2	$589.63	$76.15	$30.78	$26.06	$722.63	$20.26	1.42	$1,046.40
EL 3	$597.13	$76.15	$30.78	$26.06	$730.13	$20.26	1.42	$1,057.05
EL 4	$626.50	$76.15	$30.78	$26.06	$759.49	$20.26	1.42	$1,098.74
EL 5	$1,178.79	$86.95	$30.78	$26.06	$1,322.59	$20.26	1.42	$1,898.34

Table 12.4.22 Manufacturer Production Cost Breakdown (2012$) for HZO.SC.L

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$1,259.84	$76.16	$30.78	$26.18	$1,392.97	$20.26	1.42	$1,998.28
EL 2	$1,586.56	$86.56	$30.78	$26.18	$1,730.09	$20.26	1.42	$2,476.99

Table 12.4.23 Manufacturer Production Cost Breakdown (2012$) for HCT.SC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$410.31	$100.63	$37.39	$26.57	$574.91	$20.26	1.42	$836.64
EL 2	$412.91	$100.63	$37.39	$26.57	$577.51	$20.26	1.42	$840.33
EL 3	$416.32	$100.63	$37.39	$26.57	$580.92	$20.26	1.42	$845.17
EL 4	$420.46	$100.63	$37.39	$26.57	$585.06	$20.26	1.42	$851.04
EL 5	$478.76	$100.63	$37.39	$26.57	$643.35	$20.26	1.42	$933.83
EL 6	$487.54	$100.63	$37.39	$26.57	$652.14	$20.26	1.42	$946.31
EL 7	$514.42	$100.63	$37.39	$26.57	$679.02	$20.26	1.42	$984.47
EL 8	$864.03	$107.59	$37.39	$26.57	$1,035.59	$20.26	1.42	$1,490.80

Table 12.4.24 Manufacturer Production Cost Breakdown (2012$) for HCT.SC.L

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$496.60	$100.64	$37.39	$26.80	$661.43	$20.26	1.42	$959.50
EL 2	$501.30	$100.64	$37.39	$26.80	$666.13	$20.26	1.42	$966.17
EL 3	$508.23	$100.64	$37.39	$26.80	$673.06	$20.26	1.42	$976.01
EL 4	$566.52	$100.64	$37.39	$26.80	$731.35	$20.26	1.42	$1,058.79
EL 5	$570.66	$100.64	$37.39	$26.80	$735.49	$20.26	1.42	$1,064.66
EL 6	$579.45	$100.64	$37.39	$26.80	$744.28	$20.26	1.42	$1,077.14
EL 7	$606.32	$100.64	$37.39	$26.80	$771.16	$20.26	1.42	$1,115.31
EL 8	$1,081.70	$107.60	$37.39	$26.80	$1,253.50	$20.26	1.42	$1,800.23

Table 12.4.25 Manufacturer Production Cost Breakdown (2012$) for HCT.SC.I

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$552.63	$100.07	$37.32	$26.50	$716.52	$18.24	1.42	$1,035.70
EL 2	$554.11	$100.07	$37.32	$26.50	$718.00	$18.24	1.42	$1,037.80
EL 3	$562.90	$100.07	$37.32	$26.50	$726.79	$18.24	1.42	$1,050.29
EL 4	$590.04	$100.07	$37.32	$26.50	$753.93	$18.24	1.42	$1,088.82
EL 5	$1,227.08	$107.43	$37.32	$26.50	$1,398.34	$18.24	1.42	$2,003.87

Table 12.4.26 Manufacturer Production Cost Breakdown (2012$) for HCS.SC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$361.00	$87.08	$34.24	$26.80	$509.12	$23.30	1.42	$746.25
EL 2	$361.84	$87.08	$34.24	$26.80	$509.96	$23.30	1.42	$747.45
EL 3	$365.26	$87.08	$34.24	$26.80	$513.37	$23.30	1.42	$752.29
EL 4	$369.39	$87.08	$34.24	$26.80	$517.51	$23.30	1.42	$758.17
EL 5	$378.18	$87.08	$34.24	$26.80	$526.30	$23.30	1.42	$770.65
EL 6	$404.12	$87.08	$34.24	$26.80	$552.24	$23.30	1.42	$807.48
EL 7	$677.41	$92.58	$34.24	$26.80	$831.03	$23.30	1.42	$1,203.36

Table 12.4.27 Manufacturer Production Cost Breakdown (2012$) for HCS.SC.L

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$364.49	$94.55	$34.31	$27.09	$520.44	$23.30	1.42	$762.33
EL 2	$365.75	$94.55	$34.31	$27.09	$521.70	$23.30	1.42	$764.12
EL 3	$369.06	$94.55	$34.31	$27.09	$525.01	$23.30	1.42	$768.82
EL 4	$373.19	$94.55	$34.31	$27.09	$529.15	$23.30	1.42	$774.69
EL 5	$381.98	$94.55	$34.31	$27.09	$537.94	$23.30	1.42	$787.18
EL 6	$407.92	$94.55	$34.31	$27.09	$563.88	$23.30	1.42	$824.01
EL 7	$780.74	$100.05	$34.31	$27.09	$942.20	$23.30	1.42	$1,361.22

Table 12.4.28 Manufacturer Production Cost Breakdown (2012$) for PD.SC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$772.78	$149.87	$51.55	$37.11	$1,011.30	$37.49	1.42	$1,473.54
EL 2	$804.69	$149.87	$51.55	$37.11	$1,043.21	$37.49	1.42	$1,518.85
EL 3	$876.86	$149.87	$51.55	$37.11	$1,115.38	$37.49	1.42	$1,621.33
EL 4	$881.51	$149.87	$51.55	$37.11	$1,120.03	$37.49	1.42	$1,627.94
EL 5	$889.01	$149.87	$51.55	$37.11	$1,127.53	$37.49	1.42	$1,638.58
EL 6	$979.49	$149.87	$51.55	$37.11	$1,218.01	$37.49	1.42	$1,767.07
EL 7	$1,013.54	$149.87	$51.55	$37.11	$1,252.07	$37.49	1.42	$1,815.43
EL 8	$1,603.53	$161.39	$51.55	$37.11	$1,853.57	$37.49	1.42	$2,669.56

Table 12.4.29 Manufacturer Production Cost Breakdown (2012$) for SOC.SC.M

Efficiency Level	Material	Labor	Depre-ciation	Overhead	MPC	Shipping	Markup	MSP
EL 1	$4,583.36	$609.52	$105.61	$205.18	$5,503.68	$165.16	1.42	$7,980.38
EL 2	$4,646.89	$609.52	$105.61	$205.18	$5,567.21	$165.16	1.42	$8,070.59
EL 3	$4,675.82	$609.52	$105.61	$205.18	$5,596.14	$165.16	1.42	$8,111.67
EL 4	$4,690.81	$609.52	$105.61	$205.18	$5,611.13	$165.16	1.42	$8,132.96
EL 5	$5,018.35	$609.52	$105.61	$205.18	$5,938.67	$165.16	1.42	$8,598.07
EL 6	$5,051.68	$609.52	$105.61	$205.18	$5,971.99	$165.16	1.42	$8,645.38
EL 7	$5,155.08	$609.52	$105.61	$205.18	$6,075.40	$165.16	1.42	$8,792.22
EL 8	$6,046.47	$609.52	$105.61	$205.18	$6,966.79	$165.16	1.42	$10,057.99

12.4.8 Conversion Costs

Amended energy conservation standards typically cause manufacturers to incur one-time conversion costs to bring their production facilities and product designs into compliance with new regulations. For the MIA, DOE classified these one-time conversion costs into two major groups: capital conversion costs and product conversion costs. Capital conversion costs are one-time investments in PPE to adapt or change existing production facilities in order to fabricate and assemble new product designs that comply with amended energy conservation standards. Product conversion costs are one-time investments in research, development, industry certification testing (*i.e.*, Underwriters Laboratories (UL) certifications and NSF International certifications), 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 Capital Conversion Costs

To evaluate the level of capital conversion expenditures manufacturers would likely incur to comply with energy conservation standards, DOE used the manufacturer interviews to gather data on the level of capital investment required at each efficiency level. DOE validated manufacturer comments through estimates of capital expenditure requirements derived from the product teardown analysis and engineering model described in chapter 5 of the TSD.

In interviews, manufacturers noted that most of the design options being considered are offered as options today. As a result, many of the design options do not incur capital expenditures for new tooling or equipment. Overall, capital conversion costs are primarily driven by changes in equipment insulation. An increase in insulation thickness by one-half-inch was determined to require new foaming fixtures in most facilities. Additionally, manufacturers noted that changes in foam thickness could lead to foam reformulations. A move to vacuum insulated panels (VIPs) could require significant changes in production processes and, based on manufacturer input, was estimated to require capital expenditures that are double those of an increase in foam insulation thickness. Expected capital conversion costs for each TSL are listed in Table 12.4.30.

Table 12.4.30 Industry Cumulative Capital Conversion Cost

TSL	Capital Conversion Cost *$millions*
TSL 1	0
TSL 2	18.4
TSL 3	42.9
TSL 4	76.3
TSL 5	252.4

At TSL 1, DOE does not expect any capital conversion costs. All design options considered at this level are currently offered by manufacturers today.

At TSL 2, capital conversion costs ramp up to $18.4 million for the industry. These costs are associated with the production line updates and new tooling necessary to produce half-inch thicker insulation in the VCT.RC.L, VCS.SC.L, and VCS.SC.I equipment classes. A majority of the cost is for new foaming fixtures that can accommodate thicker foam insulation in cases.

From TSL 2 to TSL 4, the capital conversion costs for the industry steadily increase as more equipment classes will likely use thicker cases to meet the standard. At TSL 3, 8 equipment classes are expected to use thicker or improved insulation. At TSL 4, 18 of the 24 equipment classes are expected to use thicker or improved insulation. The tooling associated with thicker cases accounts for the increasing capital conversion costs.

At TSL 5, DOE models a large increase in conversion costs. This increase is associated with the incorporation of VIPs into production units. Though the industry does not use VIPs today, feedback from manufacturers indicates that VIP equipment, new jigs, and additional equipment for structural members may be required to meet the standard.

12.4.8.2 Product Conversion Costs

DOE assessed the product conversion costs at each level by integrating data from quantitative and qualitative sources. DOE considered feedback regarding the potential costs of each efficiency level from multiple manufacturers to determine conversion costs such as R&D expenditures and certification costs. Manufacturer numbers were aggregated to better reflect the industry as a whole and to protect confidential information.

Based on both manufacturer feedback and the engineering analysis, many design options were considered to be component swaps, which required substitutions of new components but did not require product redesigns. Lighting changes, fan motor substitutions, compressor upgrades, and night curtain retrofits were understood to not require significant product development investments. However, changes in evaporator coil, condenser coil, and insulation were modeled to incur development expenses. Additionally, DOE included the cost of industry certifications in the product conversion costs. Expected product conversion costs for each TSL are listed in Table 12.4.31.

Table 12.4.31 Industry Cumulative Product Conversion Cost

TSL	Product Conversion Cost *$millions*
TSL 1	8.0
TSL 2	9.9
TSL 3	10.5
TSL 4	11.2
TSL 5	68.0

At TSL 1, product conversion costs may be incurred by the industry in order to incorporate the new components in existing designs. This product conversion cost is associated with sourcing, component testing, and writing the specifications for the new components. At TSL 2, product conversion costs ramp up as manufacturers make more significant changes that require engineering investments and could necessitate new industry certification, such as UL testing and NSF testing. These testing costs and redesign costs continue to ramp up at TSL 3 and TSL 4. At TSL 5, conversion costs increase significantly as the industry must develop VIP technology for use in commercial refrigeration equipment. All design and engineering resources would go into VIP panel development.

12.4.9 Markup Scenarios

DOE used multiple 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 markup values that, 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, R&D expenses, interest, and profit— to be 1.42 for the commercial refrigeration industry. This markup is equal to the one DOE assumed in the engineering analysis. Manufacturers indicated that it is optimistic to assume that, as their MPCs 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 an upper 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 increase, 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 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. A detailed discussion of the experience curve modeling is provided in Appendix 10B of the TSD.

12.4.11 Light-Emitting Diode 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[a] ("the energy savings report"). The price projection

[a] 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.

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 commercial refrigeration industry. The following sections detail additional inputs and assumptions for commercial refrigeration equipment. 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 net present value, 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 base year of the analysis 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. The difference between the base case and a standards case INPV is an estimate of the economic impacts the TSL would have on the industry. The markup scenarios are described in greater detail in section 12.4.9.

While INPV is useful for evaluating the long-term effects of amended energy conservation standards, short-term changes in cash flow are also important indicators of the industry's financial situation. For example, a large investment over one or two years could strain the industry's access to capital. Consequently, the sharp drop in financial performance could cause investors to flee, even though recovery may be possible. Thus, a short-term disturbance can have long-term effects that the INPV cannot capture. To provide an idea of the behavior of short-term annual net cash flows, Figure 12.5.1 and Figure 12.5.2 present the annual net cash flows through 2027.

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 could have been used longer 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 be either positively or negatively affected in the year the standard takes effect.

12.5.2 Commercial Refrigeration Industry Financial Impacts

Table 12.5.1 and Table 12.5.2 provide the INPV estimates for commercial refrigeration equipment for the two markup 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 Commercial Refrigeration Equipment

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	2012$ M	1,162.0	1,158.4	1,146.9	1,135.7	1,116.1	1,136.5
Change in INPV	2012$ M	-	(3.6)	(15.2)	(26.3)	(45.9)	(25.5)
	(%)	-	(0.31)	(1.30)	(2.26)	(3.95)	(2.20)

* Numbers in parentheses indicate negative numbers.

Table 12.5.2 Preservation of Operating Profit Scenario Changes in INPV for Commercial Refrigeration Equipment

	Units	Base Case	Trial Standard Level				
			1	2	3	4	5
INPV	2012$ M	1,162.0	1,155.2	1,135.6	1,102.8	1,069.4	646.0
Change in INPV	2012$ M	-	(6.8)	(26.4)	(59.2)	(92.6)	(516.0)
	(%)	-	(0.58)	(2.27)	(5.09)	(7.97)	(44.41)

* Numbers in parentheses indicate negative numbers.

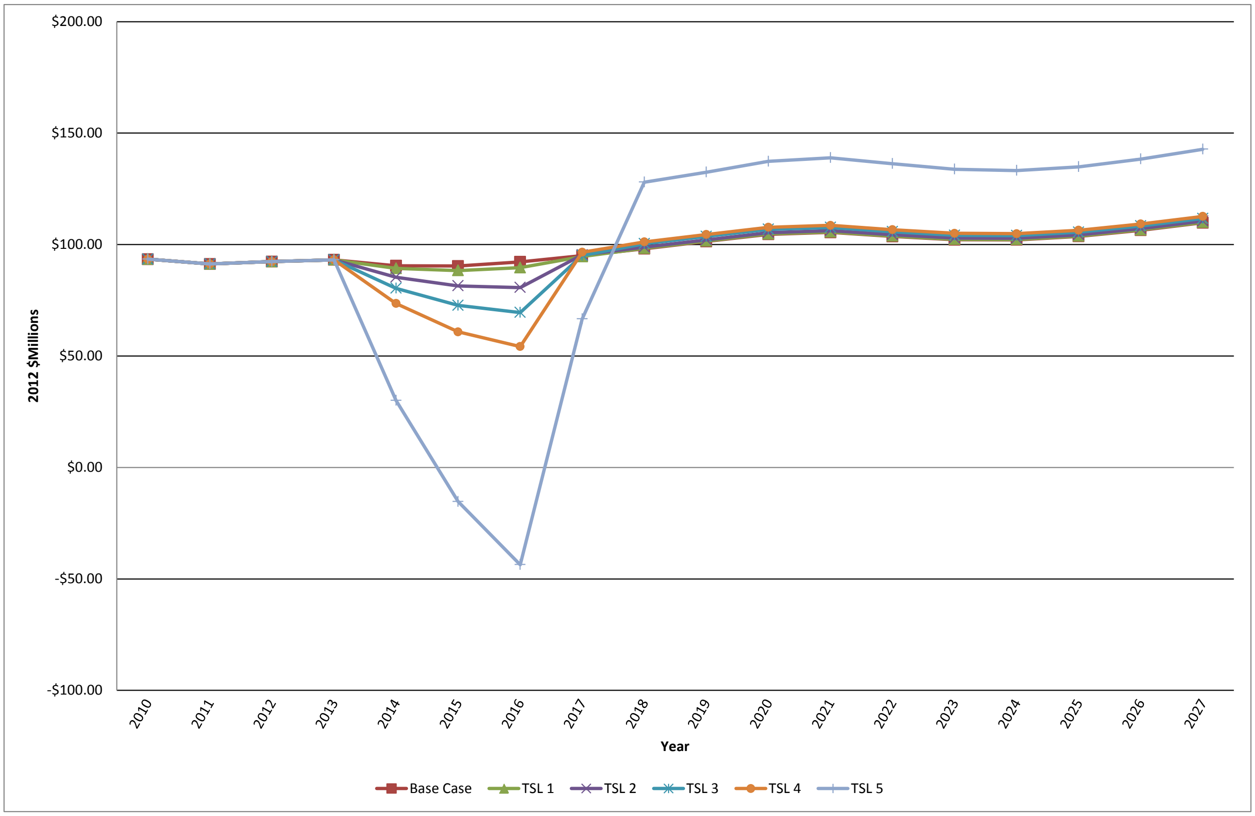

Figure 12.5.1 Annual Industry Net Cash Flows for Commercial Refrigeration Equipment (Preservation of Gross Margin Percentage Markup Scenario)

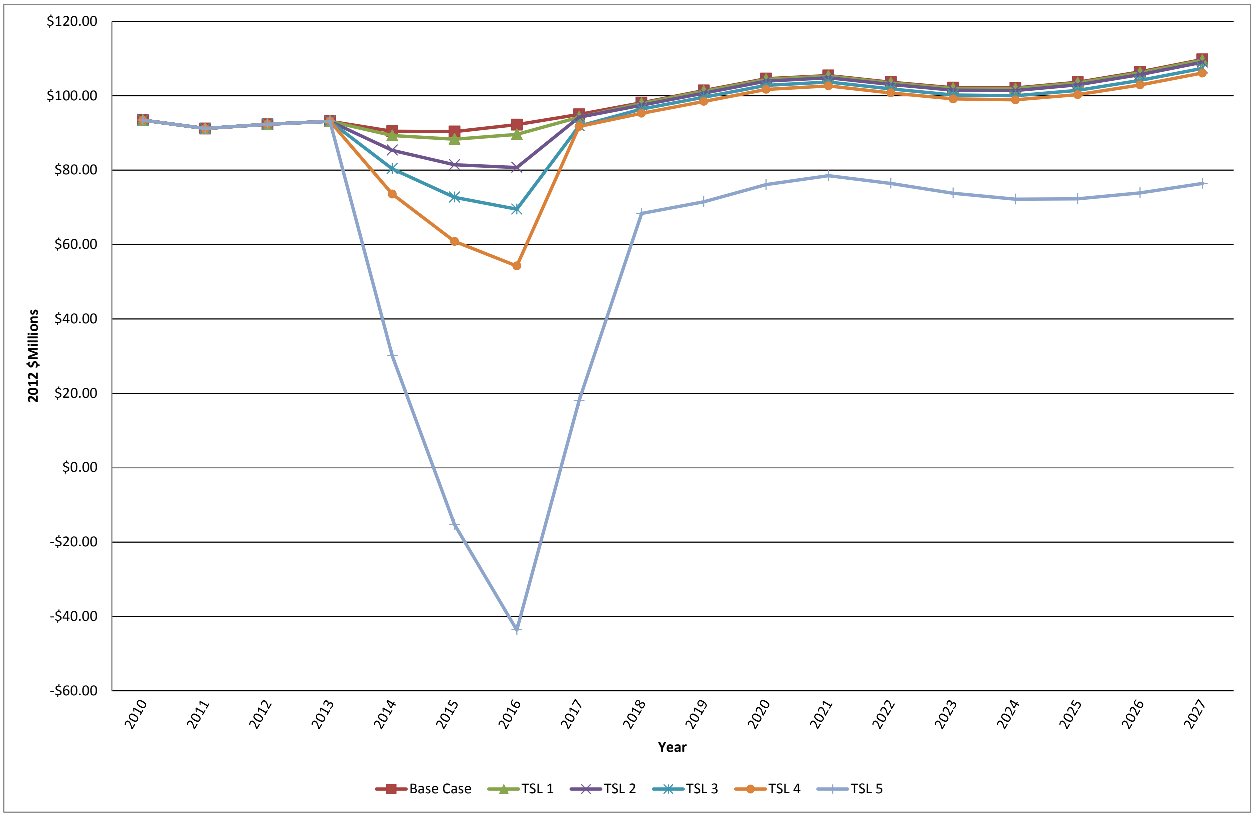

Figure 12.5.2 Annual Industry Net Cash Flows for Commercial Refrigeration Equipment (Preservation of Operating Profit Markup Scenario)

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 the category "Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing," the SBA has set a size threshold of 750 employees or less for an entity to be considered as a small business. 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, NAFEM, and NSF International), product databases (*e.g.*, Federal Trade Commission (FTC), The Thomas Register, California Energy Commission (CEC), and ENERGY STAR® databases), individual company websites, and market research tools (*e.g.*, Hoovers 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 commercial refrigeration equipment. 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 45 manufacturers in the commercial refrigeration industry, and 32 of the manufacturers identified are believed to be small businesses. As part of the MIA, the Department interviewed eight commercial refrigeration equipment manufacturers, including four small business operations. Based on the large number of small commercial refrigeration equipment 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 commercial refrigeration industry.

DOE recognizes that amended energy conservation standards can potentially have disproportionate impacts 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 notice of proposed rulemaking.

12.7 OTHER IMPACTS

12.7.1 Employment

To quantitatively assess the impacts of amended 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, the commercial refrigeration equipment shipments forecast, 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 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.

Table 12.7.1 Potential Changes in the Number of Commercial Refrigeration Equipment Production Workers in 2017

	Trial Standard Level					
	Base Case	1	2	3	4	5
Total Number of Domestic Production Workers in 2017 (assuming no changes in production locations)	3,672	3,672	3,672	3,672	3,672	3,925
Range of Potential Changes in Domestic Production Workers in 2017*	-	-3,672 to 0	-3,672 to 0	-3,672 to 0	-3,672 to 0	-3,672 to 253

* DOE presents a range of potential employment impacts, where the lower range represents the scenario in which all domestic manufacturers move production to other countries.

The employment impacts shown in Table 12.7.1 represent the potential production employment changes that could result following the compliance date of an amended energy conservation standard. 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 indicates the total number of U.S. production workers in the industry who could lose their jobs if all existing production were moved outside of the United States. Though manufacturers stated in interviews that shifts in production to foreign countries is unlikely, the industry did not provide enough information for DOE fully quantify what percentage of the industry would move production at each evaluated standard level.

The majority of design options analyzed in the engineering analysis require manufacturers to purchase more-efficient components from suppliers. These components do not require significant additional labor to assemble. A key component of a commercial refrigeration equipment unit that requires fabrication labor by the commercial refrigeration equipment manufacturer is the shell of the unit, which needs to be formed and foamed in. Although this activity may require new production equipment if thicker insulation is needed to meet higher efficiency levels, the process of building the panels would essentially remain the same, and therefore require no additional labor costs. As a result, labor needs are not expected to increase as the amended energy conservation standard increases from baseline to TSL 4.

At TSL 5, the introduction of hybrid vacuum insulation panels may lead to higher labor requirements. In general, the production and handling of hybrid VIPs will require more labor than the production of standard panels. This is due to the delicate nature of VIPs and the additional labor necessary to embed them into a hybrid panel. The additional labor and handling associated with hybrid panels account for the increase in labor at the max-tech trial standard level.

DOE notes that the employment impacts discussed here are independent of the employment impacts from the broader U.S. economy, which are documented in chapter 15 of the TSD.

12.7.2 Production Capacity

According to the majority of commercial refrigeration equipment manufacturers interviewed, amended energy conservation standards will not significantly affect manufacturers' production capacities. Any necessary redesign of commercial refrigeration equipment will not change the fundamental assembly of the equipment, but manufacturers do anticipate some potential for minor changes to tooling. The most significant of these would come as a result of any redesigns performed to accommodate additional foam insulation thickness. Additionally, most of the design options being evaluated are available on the market as product options today. Thus, DOE believe manufacturers will be able to maintain manufacturing capacity levels and continue to meet market demand under new energy conservation standards.

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 commercial refrigeration equipment manufacturers. In addition to the amended energy conservation regulations on commercial refrigeration equipment, several other Federal and State regulations apply to these products and other equipment produced by the same manufacturers.

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 disproportionately 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 Commercial Refrigeration Equipment Manufacturers

In addition to the amended energy conservation standards on commercial refrigeration equipment, other Federal regulations and pending regulations may apply to other products produced by the same manufacturers. The 2009 energy conservation standard final rule for commercial refrigeration equipment and the upcoming walk-in cooler and freezer energy conservation standard rulemaking are regulatory standards that could also affect manufacturers of commercial refrigeration in the years leading up to and after the compliance date of amended energy conservation standards for these products.

2009 Commercial Refrigeration Equipment Energy Conservation Standard Rulemaking

During interviews, some manufacturers commented on the burden of complying with a new set of standards for commercial refrigeration when the first set of standards was only recently announced in 2009 (with a compliance date of 2012). As a result, they must begin their transition to the new proposed standards when they have just begun to comply with the previous standards. Based on the MIA from the 2009 rulemaking, total conversion costs for the commercial refrigeration equipment industry would be $111.6 million, which would all be incurred in the years between the announcement date (2009) and the compliance date (2012). Total conversion costs expected for the current rulemaking at the proposed TSL are $87.5 million, which would also be incurred in the years between the announcement date (2014) and the compliance date (2017). Therefore, the commercial refrigeration equipment industry would need to make continuous investments to cover conversion costs of around $199 million from 2009 to 2017.

Walk-in Cooler and Freezer Energy Conservation Standard Rulemaking

Another DOE rulemaking that may have a significant impact on commercial refrigeration equipment manufacturers is the walk-in cooler and freezer rulemaking, which will have a compliance date of 2017. Nine commercial refrigeration equipment manufacturers also produce walk-ins, and therefore they must comply with two rulemakings that follow similar timelines. These manufacturers will incur conversion costs for both products at around the same time, which could be a significant strain on resources.

12.7.3.2 Other DOE and Federal Actions Affecting the Commercial Refrigeration Equipment Industry

Certification, Compliance, and Enforcement Rule

Many manufacturers have expressed concerns about the CC&E March 2011 final rule, which allows DOE to enforce the energy and water conservation standards for covered products and equipment, and provides for more accurate, comprehensive information about the energy and water use characteristics of products sold in the United States. The rule revises former certification regulations so that the Department has the information it needs to ensure that regulated products sold in the United States comply with the law. According to the rule, manufacturers of covered consumer products and commercial and industrial equipment must certify on an annual basis, by means of a compliance statement and a certification report, that each of their basic models meets its applicable energy conservation, water conservation, and/or design standard before it is distributed within the United States. For purposes of certification testing, the determination that a basic model complies with the applicable conservation standard must be based on sampling procedures, which currently require that a minimum of two units of a basic model must be tested in order to certify that the model is compliant (unless the product-specific regulations specify otherwise). 76 FR 12422 (March 7, 2011).

However, DOE recognizes that even a sample size of two units may not be practical for certain commercial refrigeration equipment manufacturers who build one-of-a kind customized units. Therefore, DOE is conducting a rulemaking to expand AEDM coverage and has issued a proposed rule to permit the application of AEDMs for commercial refrigeration equipment. An AEDM is a computer modeling or mathematical tool that predicts the performance of non-tested basic models. If finalized, the proposal would enable commercial refrigeration equipment manufacturers to certify all of their basic models based on testing of a minimum of one unit from five distinct basic models. DOE believes that the allowance of AEDM application would reduce manufacturer test burden for products that are highly customized, such as commercial refrigeration equipment. More information can be found at http://www1.eere.energy.gov/buildings/appliance_standards/implement_cert_and_enforce.html.

EPA and ENERGY STAR

Some stakeholders have also expressed concern regarding potential conflicts with other certification programs, in particular U.S. Environmental Protection Agency (EPA) ENERGY STAR requirements.

DOE realizes that the cumulative effect of several regulations on an industry may significantly increase the burden faced by manufacturers who need to comply with multiple regulations and certification programs from different organizations and levels of government. However, DOE notes that certain standards, such as ENERGY STAR, are optional for manufacturers.

12.7.3.3 Other Regulations That Could Impact Commercial Refrigeration Equipment Manufacturers

State Regulations

California Code of Regulations, Title 24

According to the latest California Code of Regulations, Title 24, part 6,[7] any appliance for which there is a California standard established in the Appliance Efficiency Regulations may be installed only if the manufacturer has certified to the Commission, as specified in those regulations, that the appliance complies with the applicable standard for that appliance. The Commission's appliance efficiency regulations require that the maximum daily energy consumption (in kilowatt-hours) for commercial refrigerators manufactured on or after January 1, 2010 does not exceed the following:

- refrigerators with solid doors: 0.10V + 2.04
- refrigerators with transparent doors: 0.12V + 3.34
- freezers with solid doors: 0.40V + 1.38
- freezers with transparent doors: 0.75V + 4.10
- refrigerator/freezers with solid doors: the greater of 0.27AV–0.71 or 0.70
- refrigerators with self-condensing unit designed for pull-down temperature applications: 0.126V + 3.51

Since these standards are identical to the ones prescribed in the Energy Policy Act of 2005 (EPACT 2005) and the efficiency levels set by the current rulemaking will either exceed or be equivalent to the EPACT 2005 levels, DOE does not expect the Title 24 regulations to create a cumulative regulatory burden on manufacturers. California has started a rulemaking proceeding to adopt changes to the building energy efficiency standards contained in the California Code of Regulations, Title 24, part 6. The proposed amended standards from this rulemaking will be adopted in 2014. More information can be found at: http://www.energy.ca.gov/title24/2013standards/rulemaking/index.html.

Refrigerant Management Program

The California Air Resources Board (CARB) is currently limiting the in-state use of high global warming potential (GWP) refrigerants in non-residential refrigeration systems through its Refrigerant Management Program, effective January 1, 2011. According to this new regulation, facilities with refrigeration systems that have a refrigerant capacity exceeding 50 pounds must repair leaks within 14 days of detection, maintain on-site records of all leak repairs, and keep receipts of all refrigerant purchases. The regulation applies to any person or company that installs, services, or disposes of appliances with high-GWP refrigerants. Refrigeration systems with refrigerant capacity exceeding 50 pounds typically belong to food retail operations with remote condensing racks that store refrigerant serving multiple commercial refrigeration equipment units within a business. However, commercial refrigeration equipment units in food retail are usually installed and serviced by refrigeration contractors, not manufacturers. As a result, although these CARB regulations do apply to refrigeration technicians and owners of facilities with refrigeration systems, they are unlikely to be a regulatory burden for commercial refrigeration manufacturers.

12.8 CONCLUSION

The following section summarizes the impacts for the scenarios DOE believes are most likely to capture the range of impacts on commercial refrigeration equipment 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 that cause manufacturers to experience impacts outside of this range.

For this rulemaking, TSLs are defined as shown in Table 12.8.1.

Table 12.8.1 TSLs for the Commercial Refrigeration Equipment Rulemaking

Equipment Class						
	Baseline	**TSL1**	**TSL2**	**TSL3**	**TSL4**	**TSL5**
VOP.RC.M	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
VOP.RC.L	Level 1	Level 2	Level 3	Level 4	Level 4	Level 5
VOP.SC.M	Level 1	Level 3	Level 4	Level 5	Level 6	Level 7
VCT.RC.M	Level 1	Level 2	Level 3	Level 4	Level 6	Level 7
VCT.RC.L	Level 1	Level 3	Level 4	Level 5	Level 5	Level 6
VCT.SC.M	Level 1	Level 2	Level 3	Level 4	Level 7	Level 8
VCT.SC.L	Level 1	Level 3	Level 4	Level 5	Level 7	Level 8
VCT.SC.I	Level 1	Level 3	Level 5	Level 6	Level 6	Level 7
VCS.SC.M	Level 1	Level 3	Level 5	Level 7	Level 7	Level 8
VCS.SC.L	Level 1	Level 3	Level 5	Level 6	Level 7	Level 8
VCS.SC.I	Level 1	Level 3	Level 5	Level 6	Level 6	Level 7
SVO.RC.M	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6
SVO.SC.M	Level 1	Level 3	Level 4	Level 5	Level 6	Level 7
SOC.RC.M	Level 1	Level 2	Level 3	Level 4	Level 6	Level 7
HZO.RC.M	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
HZO.RC.L	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
HZO.SC.M	Level 1	Level 2	Level 2	Level 3	Level 4	Level 5
HZO.SC.L	Level 1	Level 1	Level 1	Level 1	Level 1	Level 2
HCT.SC.M	Level 1	Level 3	Level 5	Level 6	Level 7	Level 8
HCT.SC.L	Level 1	Level 3	Level 4	Level 5	Level 7	Level 8
HCT.SC.I	Level 1	Level 2	Level 3	Level 4	Level 4	Level 5
HCS.SC.M	Level 1	Level 2	Level 3	Level 4	Level 5	Level 7
HCS.SC.L	Level 1	Level 4	Level 5	Level 6	Level 6	Level 7
PD.SC.M	Level 1	Level 2	Level 2	Level 3	Level 7	Level 8

At TSL 1, DOE estimates impacts on INPV for commercial refrigeration equipment manufacturers to range from -$6.8 million to -$3.6 million, or a change in INPV of -0.58 percent to -0.31 percent. At this potential standard level, industry free cash flow is estimated to decrease by approximately 2.85 percent to $89.6 million, compared to the base-case value of $92.2 million in the year before the compliance date (2016).

The INPV impacts at TSL 1 are relatively minor because DOE anticipates no capital conversion costs and very low product conversion costs. No capital conversion costs are expected because DOE anticipates that manufacturers would be able to make simple component swaps to meet the efficiency levels for each equipment class at this TSL. Low product conversion costs are expected for R&D to incorporate the new components into existing designs.

Under the preservation of gross margin percentage markup scenario, impacts on manufacturers are marginally negative because while manufacturers can maintain their gross margin percentages, they also incur conversion costs that slightly reduce the higher profits that they gain from increasing their selling prices to accommodate higher production costs. However, the effects of these conversion costs are more apparent in the preservation of operating profit markup scenario because manufacturers earn the same operating profit at TSL 1 as they do in the base case.

At TSL 2, DOE estimates impacts on INPV for commercial refrigeration equipment manufacturers to range from -$26.4 million to -$15.2 million, or a change in INPV of -2.27

percent to -1.30 percent. At this potential standard level, industry free cash flow is estimated to decrease by approximately 12.48 percent to $80.7 million, compared to the base-case value of $92.2 million in the year before the compliance date (2016).

Although DOE continues to expect mild impacts on the industry at TSL 2, capital conversion costs do arise for a few of the equipment classes. Most of the costs are accounted for by the potential need for a half-inch increase in the thickness of foam insulation for the VCT.RC.L, VCS.SC.L, and VCS.SC.I equipment classes. In addition, product conversion costs will also slightly increase as design options that require new UL or NSF certification are incorporated.

The changes in INPV under both the preservation of gross margin percentage markup scenario and the preservation of operating profit markup scenario are due to the same underlying factors as those in TSL 1. However, the negative impacts are slightly higher due to the introduction of possible capital conversion costs for certain equipment classes in the commercial refrigeration equipment industry.

At TSL 3, DOE estimates impacts on INPV for commercial refrigeration equipment manufacturers to range from -$59.2 million to -$26.3 million, or a change in INPV of -5.09 percent to -2.26 percent. At this potential standard level, industry free cash flow is estimated to decrease by approximately 24.65 percent to $69.5 million, compared to the base-case value of $92.2 million in the year before the compliance date (2016).

DOE expects slightly higher conversion costs at TSL 3 due to the possible need for additional foam insulation for high-volume products, such as VCS.SC.M, which accounts for approximately 27 percent of total shipments, and for VCS.SC.L, which accounts for approximately 16 percent. In total, DOE expects 8 of the 24 equipment classes to require new production equipment due to higher standards at this level.

The changes in INPV under both the preservation of gross margin percentage markup scenario and the preservation of operating profit markup scenario are due to the same underlying factors as those in TSL 1 and TSL 2. However, the negative impacts are higher due to the increase in capital conversion costs for high-volume equipment classes.

At TSL 4, DOE estimates impacts on INPV for commercial refrigeration equipment manufacturers to range from -$92.6 million to -$45.9 million, or a change in INPV of -7.97 percent to -3.95 percent. At this proposed standard level, industry free cash flow is estimated to decrease by approximately 41.19 percent to $54.2 million, compared to the base-case value of $92.2 million in the year before the compliance date (2016).

The drop in INPV at TSL 4 is primarily driven by continued increases in capital conversion costs, in particular the need for new tooling to accommodate additional foam insulation. At TSL 4, DOE expects 18 of the 24 equipment classes to require new production equipment for foam insulation due to higher standards.

The changes in INPV under both the preservation of gross margin percentage markup scenario and the preservation of operating profit markup scenario are due to the same underlying factors as those in TSL 1, TSL 2, and TSL 3. However, the negative impacts are again higher due to the increase in capital conversion costs for the majority of equipment classes.

At TSL 5, DOE estimates impacts on INPV for commercial refrigeration equipment manufacturers to range from -$516.0 million to -$25.5 million, or a change in INPV of -44.41 percent to 2.20 percent. At this potential standard level, industry free cash flow is estimated to decrease by approximately 147.31 percent to -$43.6 million, compared to the base-case value of $92.2 million in the year before the compliance date (2016).

A substantial increase in conversion costs is expected at TSL 5 due to the possible need for VIP technology. VIPs are not currently used by any commercial refrigeration equipment manufacturers and the production of VIPs would require processes different from those used to produce standard foam panels. Therefore, high R&D investments may be necessary to redesign commercial refrigeration equipment cases. It is possible that substantial new equipment would be necessary to produce VIPs for commercial refrigeration equipment applications. Furthermore, current panel production equipment that cannot be used to produce VIPs would be retired before it reaches the end of its useful life and would become a stranded asset.

The changes in INPV under both the preservation of gross margin percentage markup scenario and the preservation of operating profit markup scenario are much greater at TSL 5 due to the very high capital conversion costs that would be required for the industry to transition to the use of VIPs.

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APPENDIX 12A. GOVERNMENT REGULATORY IMPACT MODEL (GRIM) OVERVIEW

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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 product's 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	Annual Yr 2014	2015	2016	Std Yr 2017	2018	2019	2020	2021
Revenues	$ 1,458.0	$ 1,423.2	$ 1,436.3	$ 1,408.8	$ 1,420.0	$ 1,464.2	$ 1,513.2	$ 1,551.6	$ 1,586.5	$ 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	$ 140.0	$ 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%	32.15%	32.63%	33.13%	33.48%	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.

CHAPTER 13. EMISSIONS ANALYSIS

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CHAPTER 13. EMISSIONS ANALYSIS

13.1 INTRODUCTION

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), sulfur dioxide (SO_2), and mercury (Hg). The second component estimates the impacts of a potential standard on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the reductions to emissions of all species due to "upstream" activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Together, these emissions account for the full-fuel-cycle (FFC), in accordance with the U.S. Department of Energy's (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 14. DOE used the version of NEMS based on the *Annual Energy Outlook 2013 (AEO2013).*[1] Each annual version of NEMS incorporates the projected impacts of existing air quality regulations on emissions. *AEO2013* generally represents current Federal and State legislation and final implementation regulations in place as of the end of December 2012. Site emissions of CO_2 and NO_X are estimated using emissions intensity factors from a publication of the Environmental Protection Agency (EPA).[2]

Combustion emissions of CH_4 and N_2O are estimated using emissions intensity factors published by the U.S. Environmental Protection Agency (EPA), GHG Emissions Factors Hub.[a] The FFC upstream emissions are estimated based on the methodology developed by Coughlin (2013).[3] The upstream emissions include both emissions from fuel combustion during extraction, processing, and transportation of fuel, and "fugitive" emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The emissions intensity factors are expressed in terms of physical units per megawatt-hours (MWh) or million British thermal units (MMBtu) of site energy savings. Total emissions reductions are estimated using the energy savings calculated in the national impact analysis (chapter 10).

13.2 AIR QUALITY REGULATION 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 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.

[a] www.epa.gov/climateleadership/guidance/ghg-emissions.html

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 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).[b] 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. *AEO2013* 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. However, standards would be expected to reduce NO_x emissions in the States not affected by the caps, so DOE estimated NO_x emissions reductions from potential standards 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

[b] 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>

estimated mercury emissions reductions using the NEMS-BT based on *AEO2013*, which incorporates the MATS.

13.3 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 *AEO2013.* 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 kilowatt-hours). DOE uses the site energy savings multiplied by a transmission and distribution (T&D) loss factor to estimate the reduction in generation for each trial standard level (TSL). Details on the approach used may be found in Coughlin (2013).[3]

Table 13.3.1 presents the average power plant emissions factors for selected years. These power plant emissions factors are derived from the emissions factors of the plant types used to supply electricity to buildings. DOE used the commercial refrigeration end use load shape. 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 NO_x is an average for the entire U.S. The marginal calculation based on the NEMS-BT model accounts for the fact that NO_x emissions are capped in some States.

Table 13.3.1 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

13.4 UPSTREAM AND GREENHOUSE GAS EMISSIONS FACTORS

The upstream emissions accounting uses the same approach as the upstream energy accounting described in appendix 10B. See also Coughlin (2013).[3] When demand for a particular fuel is reduced, there is a corresponding reduction in the emissions from combustion of that fuel at either the building site or the power plant. The associated reduction in energy use for upstream activities leads to further reductions in emissions. These upstream emissions are defined to include the combustion emissions from the fuel used upstream, the fugitive emissions associated with the fuel used upstream, and the fugitive emissions associated with the fuel used on site.

Fugitive emissions of CO_2 occur during oil and gas production, but are small relative to combustion emissions. They comprise about 2.5 percent of total CO_2 emissions for natural gas and 1.7 percent for petroleum fuels. Fugitive emissions of methane occur during oil, gas, and coal production. Combustion emissions of CH_4 are very small, while fugitive emissions (particularly for gas production) may be relatively large. Hence, fugitive emissions make up over 99 percent of total methane emissions for natural gas, about 95 percent for coal, and 93 percent for petroleum fuels.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. For ease of application in its analysis, DOE developed all of the emissions factors using site (point of use) energy savings in the denominator. Table 13.4.1 presents the electricity upstream emissions factors for selected years. The caps that apply to power sector NO_x emissions do not apply to upstream combustion sources.

Table 13.4.1 Electricity Upstream Emissions Factors

	Unit	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	2,083	2,025	2,008	2,025	2,057	1,999

13.5 EMISSIONS IMPACT RESULTS

Table 13.5.1 presents the estimated cumulative emissions reductions for the lifetime of equipment sold in 2017−2046 for each TSL.

Table 13.5.1 Cumulative Emissions Reduction for Potential Standards for Commercial Refrigeration Equipment

	Trial Standard Level				
	1	2	3	4	5
Power Sector Emissions					
CO_2 (million metric tons)	12.22	21.83	47.55	51.77	66.05
NO_x (thousand tons)	9.05	16.18	35.23	38.36	48.93
Hg (tons)	0.03	0.05	0.10	0.11	0.14
N_2O (thousand tons)	0.26	0.47	1.02	1.11	1.42
CH_4 (thousand tons)	1.53	2.73	5.95	6.48	8.27
SO_2 (thousand tons)	16.39	29.28	63.78	69.43	88.58
Upstream Emissions					
CO_2 (million metric tons)	0.73	1.31	2.85	3.10	3.96
NO_x (thousand tons)	10.08	18.01	39.23	42.71	54.49
Hg (tons)	0.000	0.001	0.002	0.002	0.002
N_2O (thousand tons)	0.01	0.01	0.03	0.03	0.04
CH_4 (thousand tons)	61.23	109.39	238.27	259.41	330.92
SO_2 (thousand tons)	0.16	0.28	0.61	0.67	0.85
Total Emissions					
CO_2 (million metric tons)	12.95	23.14	50.41	54.88	70.01
NO_x (thousand tons)	19.14	34.19	74.46	81.07	103.42
Hg (tons)	0.03	0.05	0.10	0.11	0.14
N_2O (thousand tons)	0.27	0.48	1.05	1.15	1.46
CH_4 (thousand tons)	62.76	112.13	244.22	265.89	339.19
SO_2 (thousand tons)	16.55	29.56	64.39	70.10	89.43

Figure 13.5.1 through Figure 13.5.6 show the annual reductions for total emissions for each type of emission from each TSL. The reductions reflect the lifetime impacts of equipment sold in 2017−2046.

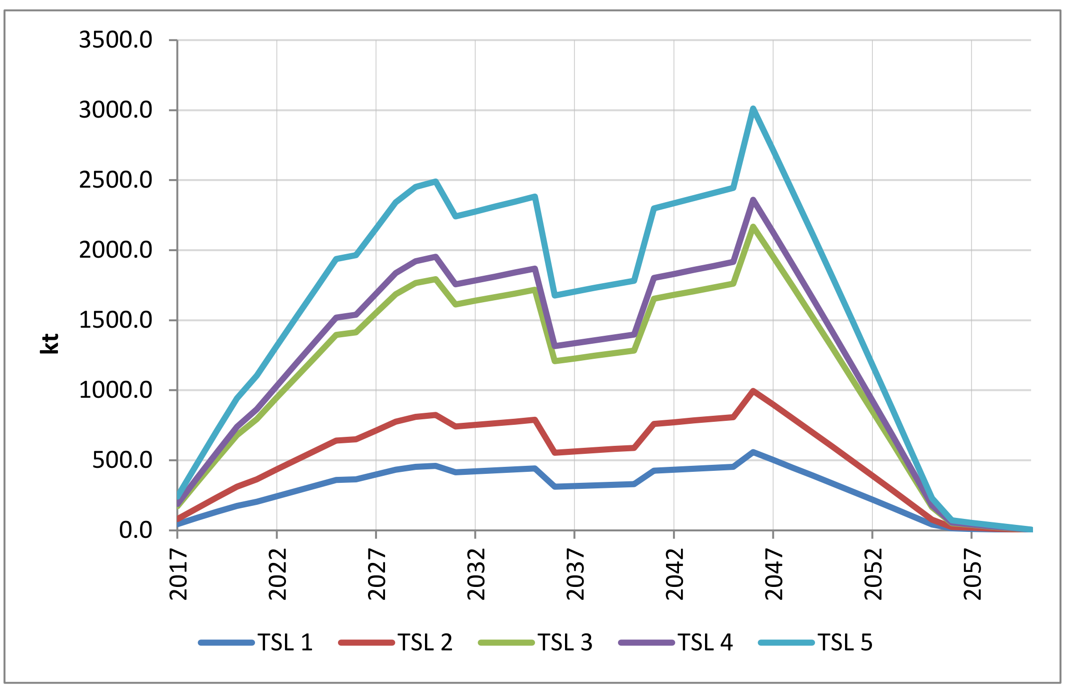

Figure 13.5.1 Commercial Refrigeration Equipment: CO_2 Total Emissions Reduction

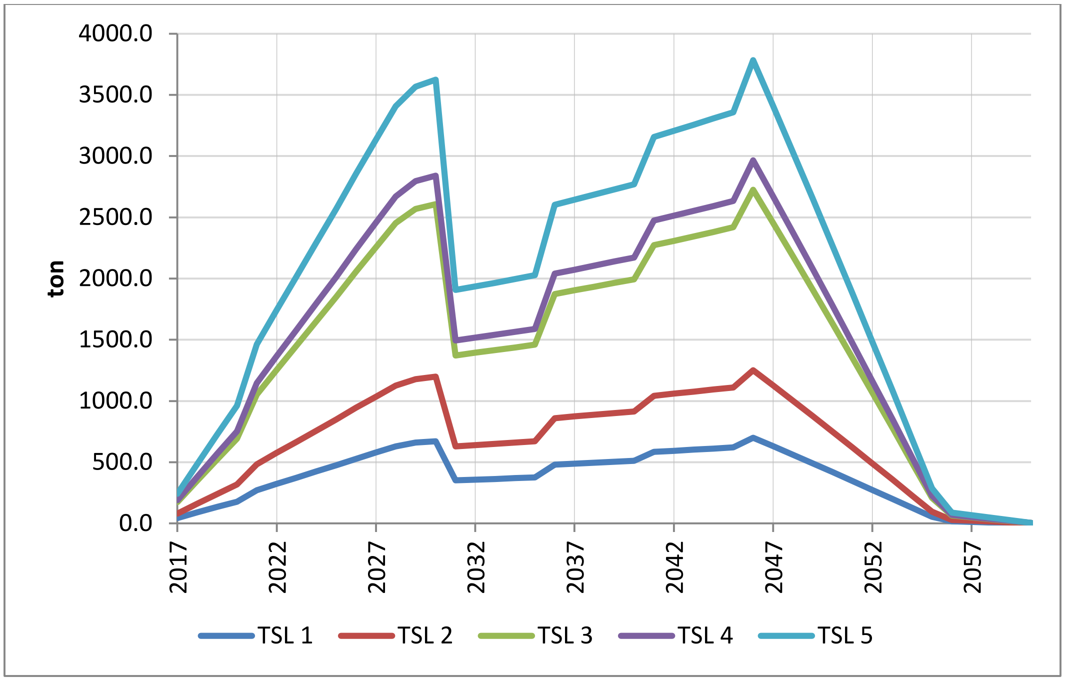

Figure 13.5.2 Commercial Refrigeration Equipment: SO_2 Total Emissions Reduction

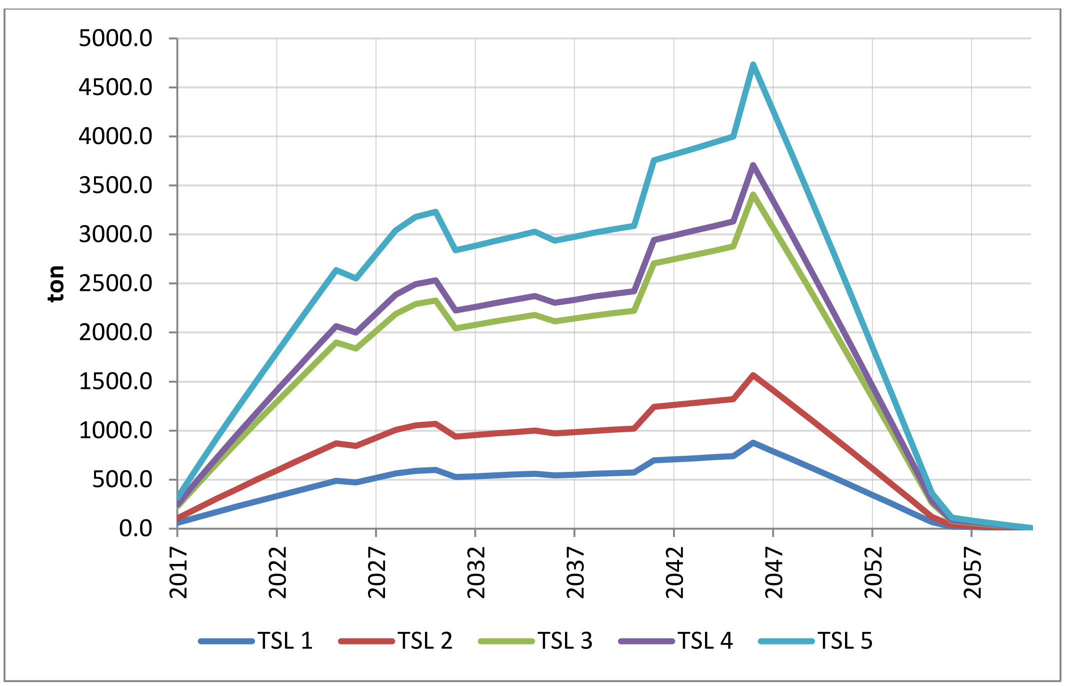

Figure 13.5.3 Commercial Refrigeration Equipment: NO_x Total Emissions Reduction

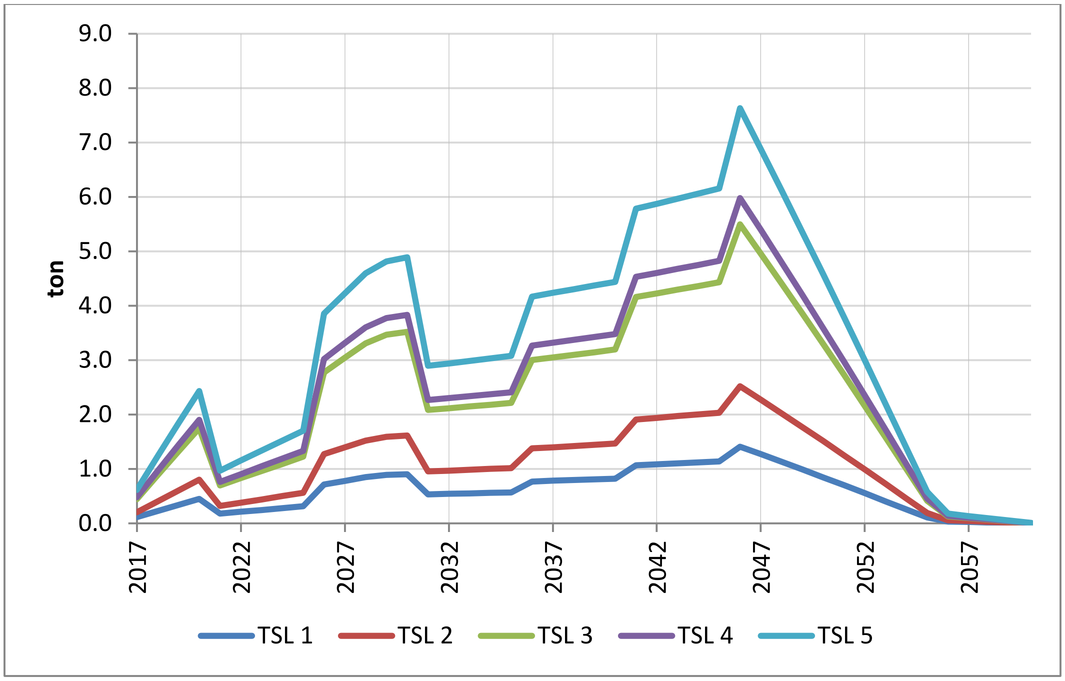

Figure 13.5.4 Commercial Refrigeration Equipment: Hg Total Emissions Reduction

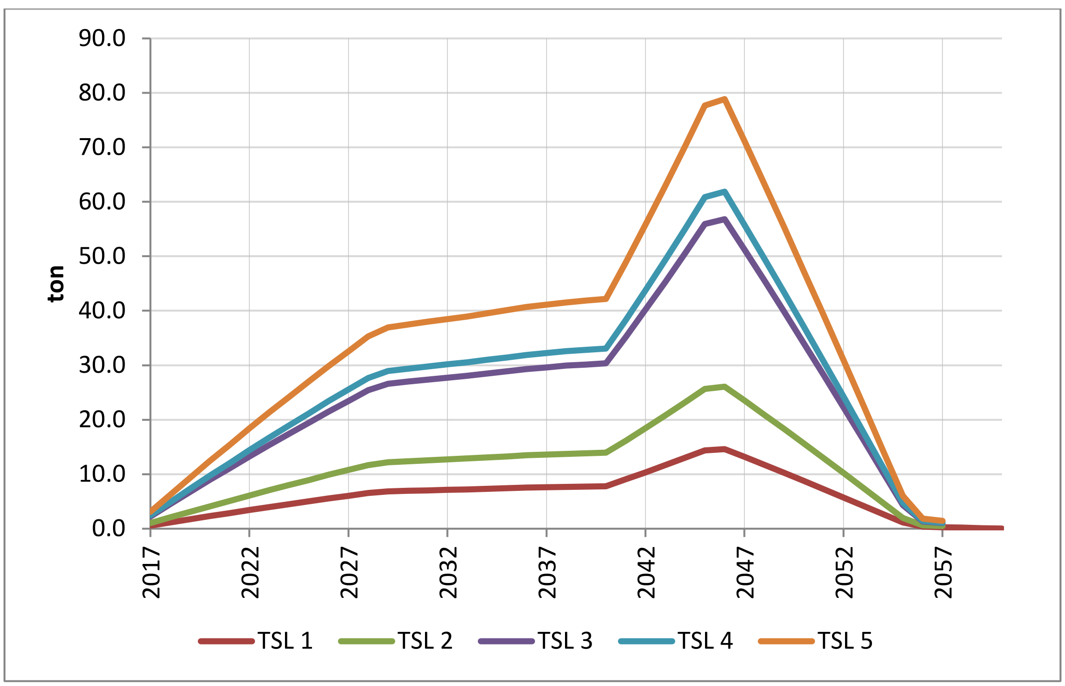

Figure 13.5.5 Commercial Refrigeration Equipment: N_2O Total Emissions Reduction

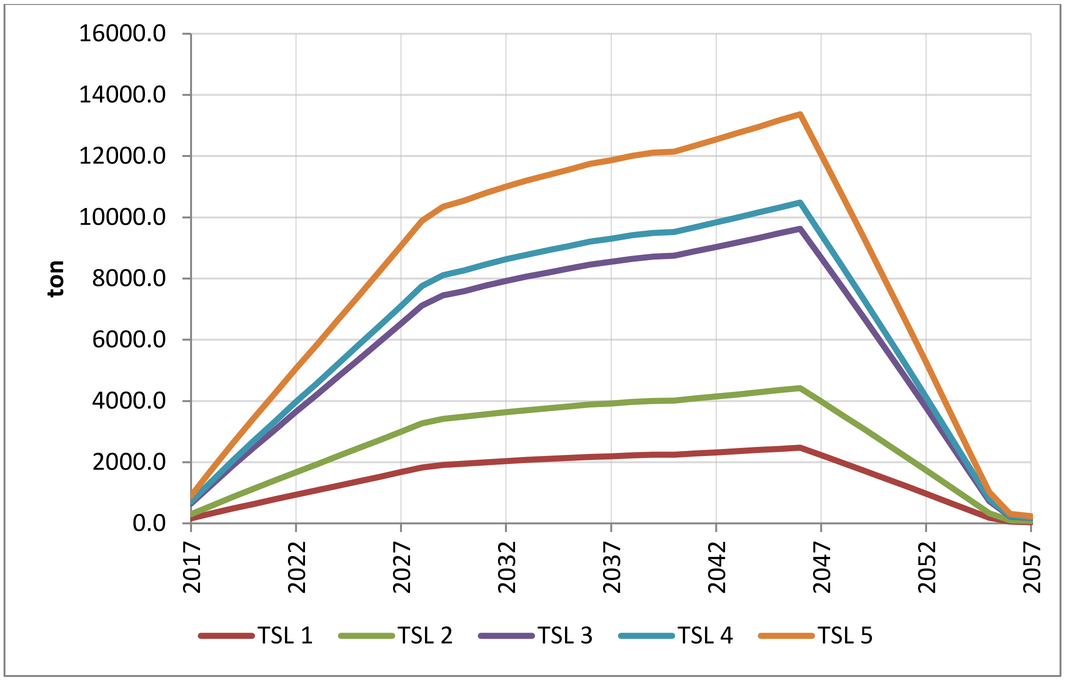

Figure 13.5.6 Commercial Refrigeration Equipment: CH_4 Total Emissions Reduction

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CHAPTER 14. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

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CHAPTER 14. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

14.1 INTRODUCTION

As part of its assessment of energy conservation standards for commercial refrigeration equipment, the U.S. Department of Energy (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 trial standard levels (TSLs) considered. This chapter summarizes the basis for the monetary values used for each of these emissions and presents the benefits estimates considered.

14.2 MONETIZING CARBON DIOXIDE EMISSIONS

14.2.1 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 CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in CO_2 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.

14.2.2 Monetizing Carbon Dioxide Emissions

When attempting to assess the incremental economic impacts of CO_2 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 CO_2 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 CO_2 emissions.

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing CO_2 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$) 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.

14.2.3 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 was conducted to select three sets of input parameters for these models: (1) climate sensitivity;

[a] The models are described in appendix 14-A of the technical support document.

(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 14.2.1 presents the values in the 2010 interagency group report,[b] which is reproduced in appendix 14-A of the notice of proposed rulemaking technical support document (NOPR 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 14.2.2 shows the updated sets of SCC estimates in 5-year increments from 2010 to 2050. The full set of annual SCC estimates between 2010 and 2050 is reported in appendix 14B of the NOPR 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. For the years after 2050, DOE applied the average annual growth rate of the SCC estimates in 2040−2050 associated with each of the four sets of values.

[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. 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. www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf

Table 14.2.1 Annual SCC Values from 2010 Interagency Report, 2010–2050 (in 2007$ 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 14.2.2 Annual SCC Values from 2013 Interagency Update, 2010–2050 (in 2007$ 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 previously mentioned 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 gross domestic product (GDP) price deflator. For each of the four cases specified, the values used for emissions in 2015 are $12.9, $40.8, $62.2, and $117 per metric ton avoided.[3]

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, the interagency report notes that damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency. Thus, 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.

14.3 VALUATION OF OTHER EMMISIONS 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 Office of Management and Budget (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.

14.4 RESULTS

Table 14.4.1 presents 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 14.4.2.

Table 14.4.1 Estimates of Global Present Value of CO_2 Emissions Reduction under Commercial Refrigeration Equipment 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	68.6	335.1	546.1	1,013.7
2	122.6	598.7	975.6	1,811.1
3	266.9	1,304.1	2,124.9	3,944.8
4	290.6	1,419.8	2,313.4	4,294.8
5	370.7	1,811.2	2,951.2	5,478.8
Upstream Emissions				
1	4.0	20.0	32.6	60.6
2	7.2	35.7	58.3	108.3
3	15.8	77.8	126.9	236.0
4	17.1	84.7	138.1	256.9
5	21.9	108.1	176.2	327.7
Total Emissions				
1	73	355	579	1,074
2	130	634	1,034	1,919
3	283	1,382	2,252	4,181
4	308	1,504	2,452	4,552
5	393	1,919	3,127	5,807

* 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 14.4.2 Estimates of Domestic Present Value of CO_2 Emissions Reduction under Commercial Refrigeration Equipment 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	4.8 to 15.8	23.5 to 77.1	38.2 to 125.6	71.0 to 233.2
2	8.6 to 28.2	41.9 to 137.7	68.3 to 224.4	126.8 to 416.6
3	18.7 to 61.4	91.3 to 299.9	148.7 to 488.7	276.1 to 907.3
4	20.3 to 66.8	99.4 to 326.5	161.9 to 532.1	300.6 to 987.8
5	26.0 to 85.3	126.8 to 416.6	206.6 to 678.8	383.5 to 1260.1
Upstream Emissions				
1	0.3 to 0.9	1.4 to 4.6	2.3 to 7.5	4.2 to 13.9
2	0.5 to 1.7	2.5 to 8.2	4.1 to 13.4	7.6 to 24.9
3	1.1 to 3.6	5.4 to 17.9	8.9 to 29.2	16.5 to 54.3
4	1.2 to 3.9	5.9 to 19.5	9.7 to 31.8	18.0 to 59.1
5	1.5 to 5.0	7.6 to 24.9	12.3 to 40.5	22.9 to 75.4
Total Emissions				
1	5.1 to 16.7	24.9 to 81.7	40.5 to 133.1	75.2 to 247.1
2	9.1 to 29.9	44.4 to 145.9	72.4 to 237.8	134.4 to 441.5
3	19.8 to 65.0	96.7 to 317.8	157.6 to 517.9	292.7 to 961.6
4	21.5 to 70.8	105.3 to 346.0	171.6 to 563.9	318.6 to 1046.9
5	27.5 to 90.3	134.3 to 441.4	218.9 to 719.3	406.5 to 1335.5

* 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 14.4.3 presents the present value of cumulative NO_x emissions reductions for each TSL, calculated using the average dollar-per-ton values and 7-percent and 3-percent discount rates.

Table 14.4.3 Estimates of Present Value of NO_x Emissions Reduction under Commercial Refrigeration Equipment Trial Standard Levels

TSL	3% discount rate	7% discount rate
	Million 2012$	
Power Sector Emissions		
1	12.0	5.6
2	21.4	10.0
3	46.6	21.7
4	50.7	23.6
5	64.7	30.1
Upstream Emissions		
1	13.4	6.2
2	24.0	11.0
3	52.3	24.0
4	56.9	26.1
5	72.6	33.3
Total Emissions		
1	25.4	11.7
2	45.4	21.0
3	98.9	45.7
4	107.6	49.8
5	137.3	63.5

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3. *Interagency* Working Group on Social Cost of Carbon, *Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. Interagency Working Group on Social Cost of Carbon,* May, 2013. United States Government. <www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf>

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APPENDIX 14A. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866

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Prepared by
Interagency Working Group on Social Cost of Carbon, United States Government

With participation by

Council of Economic Advisers
Council on Environmental Quality
Department of Agriculture
Department of Commerce
Department of Energy
Department of Transportation
Environmental Protection Agency
National Economic Council
Office of Energy and Climate Change
Office of Management and Budget
Office of Science and Technology Policy
Department of the Treasury

14A.1 EXECUTIVE SUMMARY

Under Executive Order (E.O.) 12866, agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the "social cost of carbon" (SCC) estimates presented here is to allow agencies to incorporate the social benefits of reducing carbon dioxide (CO_2) emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts.

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. It is intended to include but is not limited to changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services due to climate change.

This document presents a summary of the interagency process that developed these SCC estimates. Technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literatures.

In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC values for use in regulatory analyses (Table 14A.1.1. Three values are based on the average SCC from three integrated assessment models, at discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent higher-than-expected impacts from temperature change further out in the tails of the SCC distribution.

Table 14A.1.1 Social Cost of CO_2, 2010–2050 (2007$)

Year	Discount Rate %			
	5	3	2.5	3
	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

14A.2 MONETIZING CARBON DIOXIDE EMISSIONS

The "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. We report estimates of the social cost of carbon in dollars per metric ton of CO_2 throughout this document.[a]

When attempting to assess the incremental economic impacts of CO_2 emissions, the analyst faces a number of serious challenges. A recent report from the National Academies of Science (NRC 2009) points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases; (2) the effects of past and future emissions on the climate system; (3) the impact of changes in climate on the physical and biological environment; and (4) the translation of these environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change will raise serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the serious limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing CO_2 emissions. Under E.O. 12866, agencies

[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 (the molecular weight of CO_2 divided by the molecular weight of carbon = 44/12 = 3.67).

are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the SCC estimates presented here is to make it possible for agencies to incorporate the social benefits from reducing CO_2 emissions into cost-benefit analyses of regulatory actions that have small or "marginal" impacts on cumulative global emissions. Most Federal regulatory actions can be expected to have marginal impacts on global emissions.

For such policies, the benefits from reduced (or costs from increased) emissions in any future year can be estimated by multiplying the change in emissions in that year by the SCC value appropriate for that year. The net present value of the benefits can then be calculated by multiplying each of these future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global CO_2 emissions. For policies that have a large (non-marginal) impact on global cumulative emissions, there is a separate question of whether the SCC is an appropriate tool for calculating the benefits of reduced emissions; we do not attempt to answer that question here.

An interagency group convened on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key inputs and assumptions in order to generate SCC estimates. Agencies that actively participated in the interagency process include the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury. This process was convened by the Council of Economic Advisers and the Office of Management and Budget, with active participation and regular input from the Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions that are grounded in the existing literature. In this way, key uncertainties and model differences can more transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are $4.7, $21.4, $35.1, and $64.9 (2007$). The first three estimates are based on the average SCC across models and socio-economic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to $24 per ton of CO_2 in 2015 and $26 per ton of CO_2 in 2020. See Appendix A for the full range of annual SCC estimates from 2010 to 2050.

It is important to emphasize that the interagency process is committed to updating these estimates as the science and economic understanding of climate change and its impacts on society improves over time. Specifically, we have set a preliminary goal of revisiting the SCC values within 2 years or at such time as substantially updated models become available, and to continue to support research in this area. In the meantime, we will continue to explore the issues raised in this document and consider public comments as part of the ongoing interagency process.

14A.3 SOCIAL COST OF CARBON VALUES USED IN PAST REGULATORY ANALYSES

To date, economic analyses for Federal regulations have used a wide range of values to estimate the benefits associated with reducing CO_2 emissions. In the final model year 2011 CAFE rule, the Department of Transportation (DOT) used both a "domestic" SCC value of $2 per ton of CO_2 and a "global" SCC value of $33 per ton of CO_2 for 2007 emission reductions (2007$), increasing both values at 2.4 percent per year. It also included a sensitivity analysis at $80 per ton of CO_2. A domestic SCC value is meant to reflect the value of damages in the United States resulting from a unit change in CO_2 emissions, while a global SCC value is meant to reflect the value of damages worldwide.

A 2008 regulation proposed by DOT assumed a domestic SCC value of $7 per ton CO_2 (in 2006 dollars) for 2011 emission reductions (with a range of $0-$14 for sensitivity analysis), also increasing at 2.4 percent per year. A regulation finalized by DOE in October of 2008 used a domestic SCC range of $0 to $20 per ton CO_2 for 2007 emission reductions (2007$). In addition, EPA's 2008 Advance Notice of Proposed Rulemaking for Greenhouse Gases identified what it described as "very preliminary" SCC estimates subject to revision. EPA's global mean values were $68 and $40 per ton CO_2 for discount rates of approximately 2 percent and 3 percent, respectively (2006$ for 2007 emissions).

In 2009, an interagency process was initiated to offer a preliminary assessment of how best to quantify the benefits from reducing CO_2 emissions. To ensure consistency in how benefits are evaluated across agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced CO_2 emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the existing literature to use as interim values until a more comprehensive analysis could be conducted.

The outcome of the preliminary assessment by the interagency group was a set of five interim values: global SCC estimates for 2007 (in 2006 dollars) of $55, $33, $19, $10, and $5 per ton of CO_2. The $33 and $5 values represented model-weighted means of the published estimates produced from the most recently available versions of three integrated assessment models—DICE, PAGE, and FUND—at approximately 3 and 5 percent discount rates. The $55 and $10 values were derived by adjusting the published estimates for uncertainty in the discount rate (using factors developed by Newell and Pizer (2003)) at 3 and 5 percent discount rates, respectively. The $19 value was chosen as a central value between the $5 and $33 per ton estimates. All of these values were assumed to increase at 3 percent annually to represent growth in incremental damages over time as the magnitude of climate change increases.

These interim values represent the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of this preliminary effort were presented in several proposed and final rules and were offered for public comment in connection with proposed rules, including the joint EPA-DOT fuel economy and CO_2 tailpipe emission proposed rules.

14A.4 APPROACH AND KEY ASSUMPTIONS

Since the release of the interim values, interagency group has reconvened on a regular basis to generate improved SCC estimates. Specifically, the group has considered public comments and further explored the technical literature in relevant fields. This section details the several choices and assumptions that underlie the resulting estimates of the SCC.

It is important to recognize that a number of key uncertainties remain, and that current SCC estimates should be treated as provisional and revisable since they will evolve with improved scientific and economic understanding. The interagency group also recognizes that the existing models are imperfect and incomplete. The National Academy of Science (2009) points out that there is tension between the goal of producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of existing efforts to model these effects. Throughout this document, we highlight a number of concerns and problems that should be addressed by the research community, including research programs housed in many of the agencies participating in the interagency process to estimate the SCC.

The U.S. Government will periodically review and reconsider estimates of the SCC used for cost-benefit analyses to reflect increasing knowledge of the science and economics of climate impacts, as well as improvements in modeling. In this context, statements recognizing the limitations of the analysis and calling for further research take on exceptional significance. The interagency group offers the new SCC values with all due humility about the uncertainties embedded in them and with a sincere promise to continue work to improve them.

14A.4.1 Integrated Assessment Models

We rely on three integrated assessment models (IAMs) commonly used to estimate the SCC: the FUND, DICE, and PAGE models.[b] These models are frequently cited in the peer-reviewed literature and used in the IPCC assessment. Each model is given equal weight in the SCC values developed through this process, bearing in mind their different limitations (discussed below).

These models are useful because they combine climate processes, economic growth, and feedbacks between the climate and the global economy into a single modeling framework. At the same time, they gain this advantage at the expense of a more detailed representation of the underlying climatic and economic systems. DICE, PAGE, and FUND all take stylized, reduced-form approaches (see NRC 2009 for a more detailed discussion; see Nordhaus 2008 on the

[b] The DICE (Dynamic Integrated Climate and Economy) model by William Nordhaus evolved from a series of energy models and was first presented in 1990 (Nordhaus and Boyer 2000, Nordhaus 2008). The PAGE (Policy Analysis of the Greenhouse Effect) model was developed by Chris Hope in 1991 for use by European decision-makers in assessing the marginal impact of carbon emissions (Hope 2006, Hope 2008). The FUND (Climate Framework for Uncertainty, Negotiation, and Distribution) model, developed by Richard Tol in the early 1990s, originally to study international capital transfers in climate policy. is now widely used to study climate impacts (*e.g.*, Tol 2002a, Tol 2002b, Anthoff *et al.* 2009, Tol 2009).

possible advantages of this approach). Other IAMs may better reflect the complexity of the science in their modeling frameworks but do not link physical impacts to economic damages. There is currently a limited amount of research linking climate impacts to economic damages, which makes this exercise even more difficult. Underlying the three IAMs selected for this exercise are a number of simplifying assumptions and judgments reflecting the various modelers' best attempts to synthesize the available scientific and economic research characterizing these relationships.

The three IAMs translate emissions into changes in atmospheric greenhouse concentrations, atmospheric concentrations into changes in temperature, and changes in temperature into economic damages. The emissions projections used in the models are based on specified socio-economic (GDP and population) pathways. These emissions are translated into concentrations using the carbon cycle built into each model, and concentrations are translated into warming based on each model's simplified representation of the climate and a key parameter, climate sensitivity. Each model uses a different approach to translate warming into damages. Finally, transforming the stream of economic damages over time into a single value requires judgments about how to discount them.

Each model takes a slightly different approach to model how changes in emissions result in changes in economic damages. In PAGE, for example, the consumption-equivalent damages in each period are calculated as a fraction of GDP, depending on the temperature in that period relative to the pre-industrial average temperature in each region. In FUND, damages in each period also depend on the rate of temperature change from the prior period. In DICE, temperature affects both consumption and investment. We describe each model in greater detail here. In a later section, we discuss key gaps in how the models account for various scientific and economic processes (*e.g.*, the probability of catastrophe, and the ability to adapt to climate change and the physical changes it causes).

The parameters and assumptions embedded in the three models vary widely. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches to quantifying damages taken by the key modelers in the field. An extensive review of the literature was conducted to select three sets of input parameters for these models: climate sensitivity, socio-economic and emissions trajectories, and discount rates. A probability distribution for climate sensitivity was specified as an input into all three models. In addition, the interagency group used a range of scenarios for the 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. In DICE, these parameters are handled deterministically and represented by fixed constants; in PAGE, most parameters are represented by probability distributions. FUND was also run in a mode in which parameters were treated probabilistically.

The sensitivity of the results to other aspects of the models (*e.g.*, the carbon cycle or damage function) is also important to explore in the context of future revisions to the SCC but has not been incorporated into these estimates. Areas for future research are highlighted at the end of this document.

14A.4.1.1 The DICE Model

The DICE model is an optimal growth model based on a global production function with an extra stock variable (atmospheric CO_2 concentrations). Emission reductions are treated as analogous to investment in "natural capital." By investing in natural capital today through reductions in emissions—implying reduced consumption—harmful effects of climate change can be avoided and future consumption thereby increased.

For purposes of estimating the SCC, CO_2 emissions are a function of global GDP and the carbon intensity of economic output, with the latter declining over time due to technological progress. The DICE damage function links global average temperature to the overall impact on the world economy. It varies quadratically with temperature change to capture the more rapid increase in damages expected to occur under more extreme climate change, and is calibrated to include the effects of warming on the production of market and nonmarket goods and services. It incorporates impacts on agriculture, coastal areas (due to sea level rise), "other vulnerable market sectors" (based primarily on changes in energy use), human health (based on climate-related diseases, such as malaria and dengue fever, and pollution), non-market amenities (based on outdoor recreation), and human settlements and ecosystems. The DICE damage function also includes the expected value of damages associated with low probability, high impact "catastrophic" climate change. This last component is calibrated based on a survey of experts (Nordhaus 1994). The expected value of these impacts is then added to the other market and non-market impacts mentioned above.

No structural components of the DICE model represent adaptation explicitly, though it is included implicitly through the choice of studies used to calibrate the aggregate damage function. For example, its agricultural impact estimates assume that farmers can adjust land use decisions in response to changing climate conditions, and its health impact estimates assume improvements in healthcare over time. In addition, the small impacts on forestry, water systems, construction, fisheries, and outdoor recreation imply optimistic and costless adaptation in these sectors (Nordhaus and Boyer, 2000; Warren *et al*., 2006). Costs of resettlement due to sea level rise are incorporated into damage estimates, but their magnitude is not clearly reported. Mastrandrea's (2009) review concludes that "in general, DICE assumes very effective adaptation, and largely ignores adaptation costs."

Note that the damage function in DICE has a somewhat different meaning from the damage functions in FUND and PAGE. Because GDP is endogenous in DICE and because damages in a given year reduce investment in that year, damages propagate forward in time and reduce GDP in future years. In contrast, GDP is exogenous in FUND and PAGE, so damages in any given year do not propagate forward.[c]

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[c] Using the default assumptions in DICE 2007, this effect generates an approximately 25 percent increase in the SCC relative to damages calculated by fixing GDP. In DICE2007, the time path of GDP is endogenous. Specifically, the path of GDP depends on the rate of saving and level of abatement in each period chosen by the optimizing representative agent in the model. We made two modifications to DICE to make it consistent with EMF GDP trajectories (see next section): we assumed a fixed rate of savings of 20%, and we re-calibrated the exogenous path of total factor productivity so that DICE would produce GDP projections in the absence of warming that exactly matched the EMF scenarios.

14A.4.1.2 The PAGE Model

PAGE2002 (version 1.4epm) treats GDP growth as exogenous. It divides impacts into economic, non-economic, and catastrophic categories and calculates these impacts separately for eight geographic regions. Damages in each region are expressed as a fraction of output, where the fraction lost depends on the temperature change in each region. Damages are expressed as power functions of temperature change. The exponents of the damage function are the same in all regions but are treated as uncertain, with values ranging from 1 to 3 (instead of being fixed at 2 as in DICE).

PAGE2002 includes the consequences of catastrophic events in a separate damage sub-function. Unlike DICE, PAGE2002 models these events probabilistically. The probability of a "discontinuity" (*i.e.*, a catastrophic event) is assumed to increase with temperature above a specified threshold. The threshold temperature, the rate at which the probability of experiencing a discontinuity increases above the threshold, and the magnitude of the resulting catastrophe are all modeled probabilistically.

Adaptation is explicitly included in PAGE. Impacts are assumed to occur for temperature increases above some tolerable level (2 °C for developed countries and 0 °C for developing countries for economic impacts, and 0 °C for all regions for non-economic impacts), but adaptation is assumed to reduce these impacts. Default values in PAGE2002 assume that the developed countries can ultimately eliminate up to 90 percent of all economic impacts beyond the tolerable 2 °C increase and that developing countries can eventually eliminate 50 percent of their economic impacts. All regions are assumed to be able to mitigate 25 percent of the non-economic impacts through adaptation (Hope 2006).

14A.4.1.3 The FUND Model

Like PAGE, the FUND model treats GDP growth as exogenous. It includes separately calibrated damage functions for eight market and nonmarket sectors: agriculture, forestry, water, energy (based on heating and cooling demand), sea level rise (based on the value of land lost and the cost of protection), ecosystems, human health (diarrhea, vector-borne diseases, and cardiovascular and respiratory mortality), and extreme weather. Each impact sector has a different functional form, and is calculated separately for sixteen geographic regions. In some impact sectors, the fraction of output lost or gained due to climate change depends not only on the absolute temperature change but also on the rate of temperature change and level of regional income.[d] In the forestry and agricultural sectors, economic damages also depend on CO_2 concentrations.

Tol (2009) discusses impacts not included in FUND, noting that many are likely to have a relatively small effect on damage estimates (both positive and negative). However, he characterizes several omitted impacts as "big unknowns:" for instance, extreme climate scenarios, biodiversity loss, and effects on economic development and political violence. With regard to potentially catastrophic events, he notes, "Exactly what would cause these sorts of

[d] In the deterministic version of FUND, the majority of damages are attributable to increased air conditioning demand, while reduced cold stress in Europe, North America, and Central and East Asia results in health benefits in those regions at low to moderate levels of warming (Warren *et al*. 2006).

changes or what effects they would have are not well-understood, although the chance of any one of them happening seems low. But they do have the potential to happen relatively quickly, and if they did, the costs could be substantial. Only a few studies of climate change have examined these issues."

Adaptation is included both implicitly and explicitly in FUND. Explicit adaptation is seen in the agriculture and sea level rise sectors. Implicit adaptation is included in sectors such as energy and human health, where wealthier populations are assumed to be less vulnerable to climate impacts. For example, the damages to agriculture are the sum of three effects: (1) those due to the rate of temperature change (damages are always positive); (2) those due to the level of temperature change (damages can be positive or negative depending on region and temperature); and (3) those from CO_2 fertilization (damages are generally negative but diminishing to zero).

Adaptation is incorporated into FUND by allowing damages to be smaller if climate change happens more slowly. The combined effect of CO_2 fertilization in the agricultural sector, positive impacts to some regions from higher temperatures, and sufficiently slow increases in temperature across these sectors can result in negative economic damages from climate change.

14A.4.1.4 Damage Functions

To generate revised SCC values, we rely on the IAM modelers' current best judgments of how to represent the effects of climate change (represented by the increase in global-average surface temperature) on the consumption-equivalent value of both market and non-market goods (represented as a fraction of global GDP). We recognize that these representations are incomplete and highly uncertain. Given the paucity of data linking the physical impacts to economic damages, we were not able to identify a better way to translate changes in climate into net economic damages, short of launching our own research program.

The damage functions for the three IAMs are presented in Figure 14A.4.1 and Figure 14A.4.2, using the modeler's default scenarios and mean input assumptions. There are significant differences between the three models both at lower (Figure 14A.4.1) and higher (Figure 14A.4.2) increases in global-average temperature.

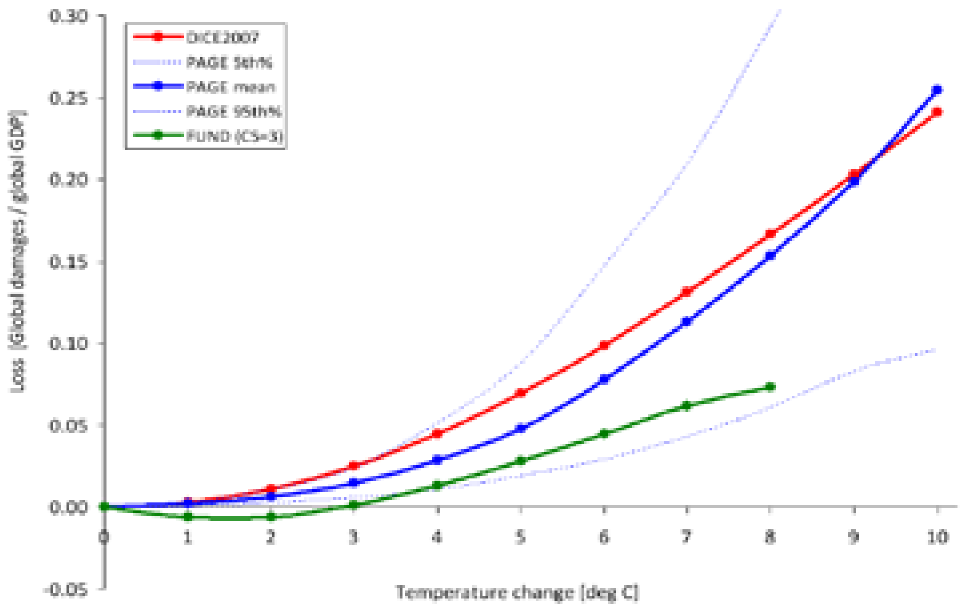

Figure 14A.4.1 Annual Consumption Loss as a Fraction of Global GDP in 2100 Due to an Increase in Annual Global Temperature in the DICE, FUND, and PAGE Models[e]

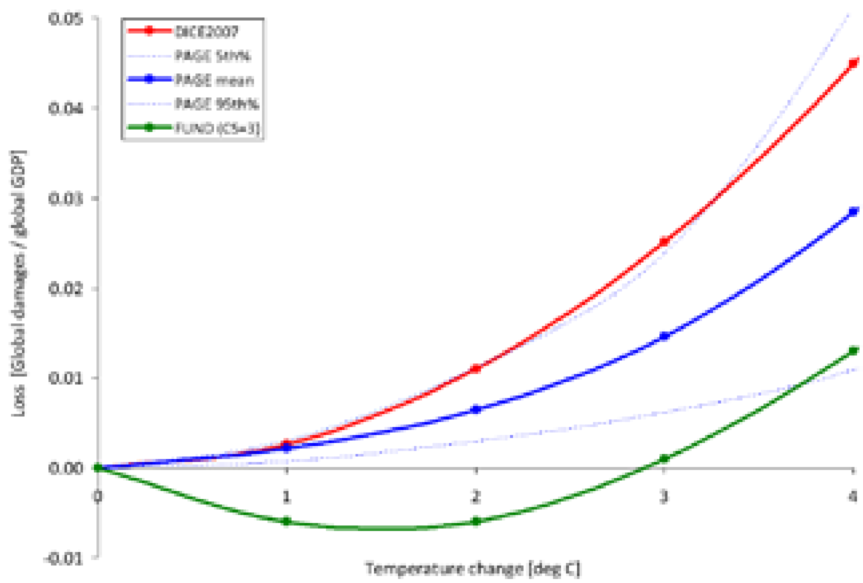

Figure 14A.4.2 Annual Consumption Loss for Lower Temperature Changes in DICE, FUND, and PAGE

[e] The x-axis represents increases in annual, rather than equilibrium, temperature, while the y-axis represents the annual stream of benefits as a share of global GDP. Each specific combination of climate sensitivity, socio-economic, and emissions parameters will produce a different realization of damages for each IAM. The damage functions represented in Figure 17A.4.1 and Figure 17A.4.2are the outcome of default assumptions. For instance, under alternate assumptions, the damages from FUND may cross from negative to positive at less than or greater than 3 °C.

The lack of agreement among the models at lower temperature increases is underscored by the fact that the damages from FUND are well below the 5th percentile estimated by PAGE, while the damages estimated by DICE are roughly equal to the 95th percentile estimated by PAGE. This is significant because at higher discount rates we expect that a greater proportion of the SCC value is due to damages in years with lower temperature increases. For example, when the discount rate is 2.5 percent, about 45 percent of the 2010 SCC value in DICE is due to damages that occur in years when the temperature is less than or equal to 3 °C. This increases to approximately 55 percent and 80 percent at discount rates of 3 and 5 percent, respectively.

These differences underscore the need for a thorough review of damage functions—in particular, how the models incorporate adaptation, technological change, and catastrophic damages. Gaps in the literature make modifying these aspects of the models challenging, which highlights the need for additional research. As knowledge improves, the Federal government is committed to exploring how these (and other) models can be modified to incorporate more accurate estimates of damages.

14A.4.2 Global versus Domestic Measures of SCC

Because of the distinctive nature of the climate change problem, we center our current attention on a global measure of SCC. This approach is the same as that taken for the interim values, but it otherwise represents a departure from past practices, which tended to put greater emphasis on a domestic measure of SCC (limited to impacts of climate change experienced within U.S. borders). As a matter of law, consideration of both global and domestic values is generally permissible; the relevant statutory provisions are usually ambiguous and allow selection of either measure.[f]

14A.4.2.1 Global SCC

Under current OMB guidance contained in Circular A-4, analysis of economically significant proposed and final regulations from the domestic perspective is required, while analysis from the international perspective is optional. However, the climate change problem is highly unusual in at least two respects. First, it involves a global externality: emissions of most greenhouse gases contribute to damages around the world even when they are emitted in the United States. Consequently, to address the global nature of the problem, the SCC must incorporate the full (global) damages caused by GHG emissions. Second, climate change presents a problem that the United States alone cannot solve. Even if the United States were to reduce its greenhouse gas emissions to zero, that step would be far from enough to avoid substantial climate change. Other countries would also need to take action to reduce emissions if significant changes in the global climate are to be avoided. Emphasizing the need for a global solution to a global problem, the United States has been actively involved in seeking international agreements to reduce emissions and in encouraging other nations, including emerging major economies, to take significant steps to reduce emissions. When these

[f] It is true that Federal statutes are presumed not to have extraterritorial effect, in part to ensure that the laws of the United States respect the interests of foreign sovereigns. But use of a global measure for the SCC does not give extraterritorial effect to federal law and hence does not intrude on such interests.

considerations are taken as a whole, the interagency group concluded that a global measure of the benefits from reducing U.S. emissions is preferable.

When quantifying the damages associated with a change in emissions, a number of analysts (*e.g.*, Anthoff *et al*. 2009a) employ "equity weighting" to aggregate changes in consumption across regions. This weighting takes into account the relative reductions in wealth in different regions of the world. A per-capita loss of $500 in GDP, for instance, is weighted more heavily in a country with a per-capita GDP of $2,000 than in one with a per-capita GDP of $40,000. The main argument for this approach is that a loss of $500 in a poor country causes a greater reduction in utility or welfare than does the same loss in a wealthy nation. Notwithstanding the theoretical claims on behalf of equity weighting, the interagency group concluded that this approach would not be appropriate for estimating a SCC value used in domestic regulatory analysis.[g] For this reason, the group concluded that using the global (rather than domestic) value, without equity weighting, is the appropriate approach.

14A.4.2.2 Domestic SCC

As an empirical matter, the development of a domestic SCC is greatly complicated by the relatively few region- or country-specific estimates of the SCC in the literature. One potential source of estimates comes from the FUND model. The resulting estimates suggest that the ratio of domestic to global benefits of emission reductions varies with key parameter assumptions. For example, with a 2.5 or 3 percent discount rate, the U.S. benefit is about 7–10 percent of the global benefit, on average, across the scenarios analyzed. Alternatively, if the fraction of GDP lost due to climate change is assumed to be similar across countries, the domestic benefit would be proportional to the U.S. share of global GDP, which is currently about 23 percent.[h]

On the basis of this evidence, the interagency workgroup determined that a range of values from 7 to 23 percent should be used to adjust the global SCC to calculate domestic effects. Reported domestic values should use this range. It is recognized that these values are approximate, provisional, and highly speculative. There is no *a priori* reason why domestic benefits should be a constant fraction of net global damages over time. Further, FUND does not account for how damages in other regions could affect the United States (*e.g.*, global migration, economic and political destabilization). If more accurate methods for calculating the domestic SCC become available, the Federal government will examine these to determine whether to update its approach.

14A.4.3 Valuing Non-CO_2 Emissions

While CO_2 is the most prevalent greenhouse gas emitted into the atmosphere, the U.S. included five other greenhouse gases in its recent endangerment finding: methane, nitrous oxide,

[g] It is plausible that a loss of $X inflicts more serious harm on a poor nation than on a wealthy one, but development of the appropriate "equity weight" is challenging. Emissions reductions also impose costs, and hence a full account would have to consider that a given cost of emissions reductions imposes a greater utility or welfare loss on a poor nation than on a wealthy one. Even if equity weighting—for both the costs and benefits of emissions reductions—is appropriate when considering the utility or welfare effects of international action, the interagency group concluded that it should not be used in developing an SCC for use in regulatory policy at this time.
[h] Based on 2008 GDP (in current US dollars) from the *World Bank Development Indicators Report*.

hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride. The climate impact of these gases is commonly discussed in terms of their 100-year global warming potential (GWP). GWP measures the ability of different gases to trap heat in the atmosphere (*i.e.*, radiative forcing per unit of mass) over a particular timeframe relative to CO_2. However, because these gases differ in both radiative forcing and atmospheric lifetimes, their relative damages are not constant over time. For example, because methane has a short lifetime, its impacts occur primarily in the near term and thus are not discounted as heavily as those caused by longer-lived gases. Impacts other than temperature change also vary across gases in ways that are not captured by GWP. For instance, CO_2 emissions, unlike methane and other greenhouse gases, contribute to ocean acidification. Likewise, damages from methane emissions are not offset by the positive effect of CO_2 fertilization. Thus, transforming gases into CO_2-equivalents using GWP, and then multiplying the carbon-equivalents by the SCC, would not result in accurate estimates of the social costs of non-CO_2 gases.

In light of these limitations, and the significant contributions of non-CO_2 emissions to climate change, further research is required to link non-CO_2 emissions to economic impacts. Such work would feed into efforts to develop a monetized value of reductions in non-CO_2 greenhouse gas emissions. As part of ongoing work to further improve the SCC estimates, the interagency group hopes to develop methods to value these other greenhouse gases. The goal is to develop these estimates by the time we issue revised SCC estimates for CO_2 emissions.

14A.4.4 Equilibrium Climate Sensitivity

Equilibrium climate sensitivity (ECS) is a key input parameter for the DICE, PAGE, and FUND models.[i] It is defined as the long-term increase in the annual global-average surface temperature from a doubling of atmospheric CO_2 concentration relative to pre-industrial levels (or stabilization at a concentration of approximately 550 parts per million (ppm)). Uncertainties in this important parameter have received substantial attention in the peer-reviewed literature.

The most authoritative statement about equilibrium climate sensitivity appears in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC):

> Basing our assessment on a combination of several independent lines of evidence…including observed climate change and the strength of known feedbacks simulated in [global climate models], we conclude that the global mean equilibrium warming for doubling CO_2, or 'equilibrium climate sensitivity,' is likely to lie in the range 2 °C to 4.5 °C, with a most likely value of about 3 °C. Equilibrium climate sensitivity is very likely larger than 1.5 °C.[j]
>
> For fundamental physical reasons as well as data limitations, values substantially higher than 4.5 °C still cannot be excluded, but agreement with observations and proxy data is generally

[i] The equilibrium climate sensitivity includes the response of the climate system to increased greenhouse gas concentrations over the short to medium term (up to 100–200 years), but it does not include long-term feedback effects due to possible large-scale changes in ice sheets or the biosphere, which occur on a time scale of many hundreds to thousands of years (*e.g.*, Hansen *et al*. 2007).

[j] This is in accord with the judgment that it "is likely to lie in the range 2 °C to 4.5 °C" and the IPCC definition of "likely" as greater than 66 percent probability (Le Treut *et al*. 2007). "Very likely" indicates a greater than 90 percent probability.

worse for those high values than for values in the 2 °C to 4.5 °C range. (Meehl *et al*. 2007, p. 799)

After consulting with several lead authors of this chapter of the IPCC report, the interagency workgroup selected four candidate probability distributions and calibrated them to be consistent with the above statement: Roe and Baker (2007), log-normal, gamma, and Weibull. Table 17A.4.1 gives summary statistics for the four calibrated distributions.

Table 14A.4.1 Summary Statistics for Four Calibrated Climate Sensitivity Distributions

Rank	Roe & Baker	Log-Normal	Gamma	Weibull
Pr(ECS < 1.5 °C)	0.013	0.050	0.070	0.102
Pr(2 °C < ECS < 4.5 °C)	0.667	0.667	0.667	0.667
5th Percentile	1.72	1.49	1.37	1.13
10th Percentile	1.91	1.74	1.65	1.48
Mode	2.34	2.52	2.65	2.90
Median (50th percentile)	3.00	3.00	3.00	3.00
Mean	3.50	3.28	3.19	3.07
90th Percentile	5.86	5.14	4.93	4.69
95th Percentile	7.14	5.97	5.59	5.17

Each distribution was calibrated by applying three constraints from the IPCC:

(1) a median equal to 3 °C, to reflect the judgment of "a most likely value of about 3 °C;"[k]
(2) two-thirds probability that the equilibrium climate sensitivity lies between 2 and 4.5 °C; and
(3) zero probability that it is less than 0 °C or greater than 10 °C (Hegerl *et al.* 2006, p. 721).

We selected the calibrated Roe and Baker distribution from the four candidates for two reasons. First, the Roe and Baker distribution is the only one of the four that is based on a theoretical understanding of the response of the climate system to increased greenhouse gas concentrations (Roe and Baker 2007; Roe 2008). In contrast, the other three distributions are mathematical functions that are arbitrarily chosen based on simplicity, convenience, and general shape. The Roe and Baker distribution results from three assumptions about climate response: (1) absent feedback effects, the equilibrium climate sensitivity is equal to 1.2 °C; (2) feedback factors are proportional to the change in surface temperature; and (3) uncertainties in feedback factors are normally distributed. There is widespread agreement on the first point and the second and third points are common assumptions.

Second, the calibrated Roe and Baker distribution better reflects the IPCC judgment that "values substantially higher than 4.5°C still cannot be excluded." Although the IPCC made no

[k] Strictly speaking, "most likely" refers to the mode of a distribution rather than the median, but common usage would allow the mode, median, or mean to serve as candidates for the central or "most likely" value and the IPCC report is not specific on this point. For the distributions we considered, the median was between the mode and the mean. For the Roe and Baker distribution, setting the median equal to 3 °C, rather than the mode or mean, gave a 95th percentile that is more consistent with IPCC judgments and the literature. For example, setting the mean and mode equal to 3 °C produced 95th percentiles of 5.6 and 8.6 °C, respectively, which are in the lower and upper end of the range in the literature. Finally, the median is closer to 3 °C than is the mode for the truncated distributions selected by the IPCC (Hegerl *et al*. 2006); the average median is 3.1 °C and the average mode is 2.3 °C, which is most consistent with a Roe and Baker distribution with the median set equal to 3 °C.

quantitative judgment, the 95th percentile of the calibrated Roe & Baker distribution (7.1 °C) is much closer to the mean and the median (7.2 °C) of the 95th percentiles of 21 previous studies summarized by Newbold and Daigneault (2009). It is also closer to the mean (7.5 °C) and median (7.9 °C) of the nine truncated distributions examined by the IPCC (Hegerl *et al*. 2006) than are the 95th percentiles of the three other calibrated distributions (5.2–6.0 °C).

Finally, we note the IPCC judgment that the equilibrium climate sensitivity "is very likely larger than 1.5°C." Although the calibrated Roe & Baker distribution, for which the probability of equilibrium climate sensitivity being greater than 1.5 °C is almost 99 percent, is not inconsistent with the IPCC definition of "very likely" as "greater than 90 percent probability," it reflects a greater degree of certainty about very low values of ECS than was expressed by the IPCC.

To show how the calibrated Roe and Baker distribution compares to different estimates of the probability distribution function of equilibrium climate sensitivity in the empirical literature, Figure 14A.4.3 overlays it on Figure 17A.9.2 from the IPCC Fourth Assessment Report. These functions are scaled to integrate to unity between 0 °C and 10 °C. The horizontal bars show the respective 5 percent to 95 percent ranges; dots indicate the median estimate.[1]

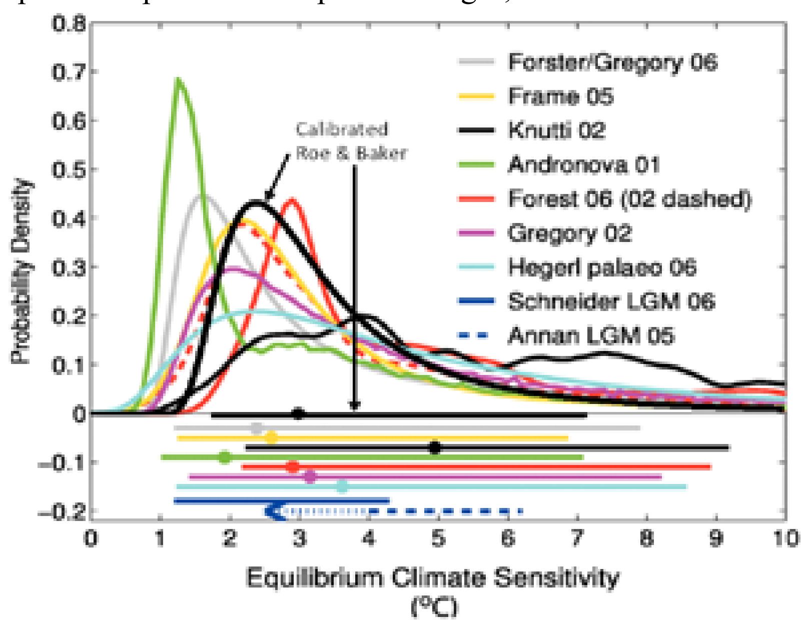

Figure 14A.4.3 Estimates of the Probability Density Function for Equilibrium Climate Sensitivity

[1] The estimates based on instrumental data are from Andronova and Schlesinger (2001), Forest et al. (2002; dashed line, anthropogenic forcings only), Forest *et al*. (2006; solid line, anthropogenic and natural forcings), Gregory *et al*. (2002), Knutti *et al*. (2002), Frame *et al*. (2005), and Forster and Gregory (2006). Hegerl *et al*. (2006) are based on multiple palaeoclimatic reconstructions of north hemisphere mean temperatures over the last 700 years. Also shown are the 5–95 percent approximate ranges for two estimates from the last glacial maximum (dashed, Annan *et al*. 2005; solid, Schneider von Deimling *et al*. 2006), which are based on models with different structural properties.

14A.4.5 Socio-Economic and Emissions Trajectories

Another key issue considered by the interagency group is how to select the set of socio-economic and emissions parameters for use in PAGE, DICE, and FUND. Socio-economic pathways are closely tied to climate damages because, all else equal, more and wealthier people tend to emit more greenhouse gases and also have a higher (absolute) willingness to pay to avoid climate disruptions. For this reason, we consider how to model several input parameters in tandem: GDP, population, CO_2 emissions, and non-CO_2 radiative forcing. A wide variety of scenarios have been developed and used for climate change policy simulations (*e.g.*, SRES 2000, CCSP 2007, EMF 2009). In determining which scenarios are appropriate for inclusion, we aimed to select scenarios that span most of the plausible ranges of outcomes for these variables.

To accomplish this task in a transparent way, we decided to rely on the recent Stanford Energy Modeling Forum exercise, EMF-22, which uses ten well-recognized models to evaluate substantial, coordinated global action to meet specific stabilization targets. A key advantage of relying on these data is that GDP, population, and emission trajectories are internally consistent for each model and scenario evaluated. The EMF-22 modeling effort also is preferable to the IPCC SRES due to their age (SRES were developed in 1997) and the fact that 3 of 4 of the SRES scenarios are now extreme outliers in one or more variables. Although the EMF-22 scenarios have not undergone the same level of scrutiny as the SRES scenarios, they are recent, peer-reviewed, published, and publicly available.

To estimate the SCC for use in evaluating domestic policies that will have a small effect on global cumulative emissions, we use socio-economic and emission trajectories that span a range of plausible scenarios. Five trajectories were selected from EMF-22 (Table 14A.4.2). Four of these represent potential business-as-usual (BAU) growth in population, wealth, and emissions and are associated with CO_2 (only) concentrations ranging from 612 to 889 ppm in 2100. One represents an emissions pathway that achieves stabilization at 550 ppm CO_2e (*i.e.*, CO_2-only concentrations of 425–484 ppm or a radiative forcing of 3.7 W/m^2) in 2100, a lower-than-BAU trajectory.[m] Out of the 10 models included in the EMF-22 exercise, we selected the trajectories used by MiniCAM, MESSAGE, IMAGE, and the optimistic scenario from MERGE. For the BAU pathways, we used the GDP, population, and emission trajectories from each of these four models. For the 550 ppm CO_2e scenario, we averaged the GDP, population, and emission trajectories implied by these same four models.

[m] Such an emissions path would be consistent with widespread action by countries to mitigate GHG emissions, though it could also result from technological advances. It was chosen because it represents the most stringent case analyzed by the EMF-22 where all the models converge: a 550 ppm, not to exceed, full participation scenario.

Table 14A.4.2 Socioeconomic and Emissions Projections from Select EMF-22 Reference Scenarios

Reference Fossil and Industrial CO_2 Emissions *$GtCO_2/yr$*						
EMF – 22 Based Scenarios	**2000**	**2010**	**2020**	**2030**	**2050**	**2100**
IMAGE	26.6	31.9	36.9	40.0	45.3	60.1
MERGE Optimistic	24.6	31.5	37.6	45.1	66.5	117.9
MESSAGE	26.8	29.2	37.6	42.1	43.5	42.7
MiniCAM	26.5	31.8	38.0	45.1	57.8	80.5
550 ppm average	26.2	31.1	33.2	32.4	20.0	12.8
Reference GDP ***market exchange rates in trillion 2005$***[n]						
EMF – 22 Based Scenarios	**2000**	**2010**	**2020**	**2030**	**2050**	**2100**
IMAGE	38.6	53.0	73.5	97.2	156.3	396.6
MERGE Optimistic	36.3	45.9	59.7	76.8	122.7	268.0
MESSAGE	38.1	52.3	69.4	91.4	153.7	334.9
MiniCAM	36.1	47.4	60.8	78.9	125.7	369.5
550 ppm average	37.1	49.6	65.6	85.5	137.4	337.9
Global Population ***billions***						
EMF – 22 Based Scenarios	**2000**	**2010**	**2020**	**2030**	**2050**	**2100**
IMAGE	6.1	6.9	7.6	8.2	9.0	9.1
MERGE Optimistic	6.0	6.8	7.5	8.2	9.0	9.7
MESSAGE	6.1	6.9	7.7	8.4	9.4	10.4
MiniCAM	6.0	6.8	7.5	8.1	8.8	8.7
550 ppm average	6.1	6.8	7.6	8.2	8.7	9.1

We explore how sensitive the SCC is to various assumptions about how the future will evolve without prejudging what is likely to occur. The interagency group considered formally assigning probability weights to different states of the world, but this proved challenging to do in an analytically rigorous way given the dearth of information on the likelihood of a full range of future socio-economic pathways.

There are a number of caveats. First, EMF BAU scenarios represent the modelers' judgment of the most likely pathway absent mitigation policies to reduce greenhouse gas emissions, rather than the wider range of possible outcomes. Nevertheless, these views of the

[n] While the EMF-22 models used market exchange rates (MER) to calculate global GDP, it is also possible to use purchasing power parity (PPP), which takes into account the different price levels across countries, so it more accurately describes relative standards of living across countries. MERs tend to make low-income countries appear poorer than they actually are. Because many models assume convergence in per capita income over time, use of MER-adjusted GDP gives rise to projections of higher economic growth in low income countries. There is an ongoing debate about how much this will affect estimated climate impacts. Critics of the use of MER argue that it leads to overstated economic growth and hence a significant upward bias in projections of greenhouse gas emissions, and unrealistically high future temperatures (*e.g.*, Castles and Henderson 2003). Others argue that convergence of the emissions-intensity gap across countries at least partially offset the overstated income gap so that differences in exchange rates have less of an effect on emissions (Holtsmark and Alfsen, 2005; Tol, 2006). Nordhaus (2007b) argues that the ideal approach is to use superlative PPP accounts (*i.e.*, using cross-sectional PPP measures for relative incomes and outputs and national accounts price and quantity indexes for time-series extrapolations). However, he notes that it important to keep this debate in perspective; it is by no means clear that exchange-rate-conversion issues are as important as uncertainties about population, technological change, or the many geophysical uncertainties.

most likely outcome span a wide range, from the more optimistic (*e.g.*, abundant low-cost, low-carbon energy) to more pessimistic (*e.g.*, constraints on the availability of nuclear and renewables).[o] Second, the socio-economic trajectories associated with a 550 ppm CO_2e concentration scenario are not derived from an assessment of what policy is optimal from a benefit-cost standpoint. Rather, it is indicative of one possible future outcome. The emission trajectories underlying some BAU scenarios (*e.g.*, MESSAGE's 612 ppm) also are consistent with some modest policy action to address climate change.[p] We chose not to include socio-economic trajectories that achieve even lower GHG concentrations at this time, given the difficulty many models had in converging to meet these targets.

For comparison purposes, the Energy Information Agency in its 2009 *Annual Energy Outlook* projected that global CO_2 emissions will grow to 30.8, 35.6, and 40.4 gigatons in 2010, 2020, and 2030, respectively, while world GDP is projected to be $51.8, $71.0 and $93.9 trillion (2005$ using market exchange rates) in 2010, 2020, and 2030, respectively. These projections are consistent with one or more EMF-22 scenarios. Likewise, the United Nations' 2008 Population Prospect projects population will grow from 6.1 billion people in 2000 to 9.1 billion people in 2050, which is close to the population trajectories for the IMAGE, MiniCAM, and MERGE models.

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane, nitrous oxide, fluorinated greenhouse gases, and net land use CO_2 emissions out to 2100. These assumptions also are used in the three models while retaining the default radiative forcings due to other factors (*e.g.*, aerosols and other gases). See the Appendix for greater detail.

14A.4.6 Discount Rate

The choice of a discount rate, especially over long periods of time, raises highly contested and exceedingly difficult questions of science, economics, philosophy, and law. Although it is well understood that the discount rate has a large influence on the current value of future damages, there is no consensus about what rates to use in this context. Because CO_2 emissions are long-lived, subsequent damages occur over many years. In calculating the SCC, we first estimate the future damages to agriculture, human health, and other market and non-market sectors from an additional unit of CO_2 emitted in a particular year in terms of reduced consumption (or consumption equivalents) due to the impacts of elevated temperatures, as represented in each of the three IAMs. Then we discount the stream of future damages to its present value in the year when the additional unit of emissions was released using the selected discount rate, which is intended to reflect society's marginal rate of substitution between consumption in different time periods.

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[o] For instance, in the MESSAGE model's reference case total primary energy production from nuclear, biomass, and non-biomass renewables is projected to increase from about 15 percent of total primary energy in 2000 to 54 percent in 2100. In comparison, the MiniCAM reference case shows 10 percent in 2000 and 21 percent in 2100.
[p] For example, MiniCAM projects if all non-US OECD countries reduce CO_2 emissions to 83 percent below 2005 levels by 2050 (per the G-8 agreement) but all other countries continue along a BAU path CO_2 concentrations in 2100 would drop from 794 ppmv in its reference case to 762 ppmv.

For rules with both intra- and intergenerational effects, agencies traditionally employ constant discount rates of both 3 percent and 7 percent in accordance with OMB Circular A-4. As Circular A-4 acknowledges, however, the choice of discount rate for intergenerational problems raises distinctive problems and presents considerable challenges. After reviewing those challenges, Circular A-4 states, "If your rule will have important intergenerational benefits or costs you might consider a further sensitivity analysis using a lower but positive discount rate in addition to calculating net benefits using discount rates of 3 and 7 percent." For the specific purpose of developing the SCC, we adapt and revise that approach here.

Arrow *et al.* (1996) outlined two main approaches to determine the discount rate for climate change analysis, which they labeled "descriptive" and "prescriptive." The descriptive approach reflects a positive (non-normative) perspective based on observations of people's actual choices—*e.g.*, savings versus consumption decisions over time, and allocations of savings among more and less risky investments. Advocates of this approach generally call for inferring the discount rate from market rates of return "because of a lack of justification for choosing a social welfare function that is any different than what decision makers [individuals] actually use" (Arrow *et al*. 1996).

One theoretical foundation for the cost-benefit analyses in which the social cost of carbon will be used—the Kaldor-Hicks potential-compensation test—also suggests that market rates should be used to discount future benefits and costs, because it is the market interest rate that would govern the returns potentially set aside today to compensate future individuals for climate damages that they bear (*e.g.*, Just *et al*. 2004). As some have noted, the word "potentially" is an important qualification; there is no assurance that such returns will actually be set aside to provide compensation, and the very idea of compensation is difficult to define in the intergenerational context. On the other hand, societies provide compensation to future generations through investments in human capital and the resulting increase in knowledge, as well as infrastructure and other physical capital.

The prescriptive approach specifies a social welfare function that formalizes the normative judgments that the decision-maker wants explicitly to incorporate into the policy evaluation—*e.g.*, how inter-personal comparisons of utility should be made, and how the welfare of future generations should be weighed against that of the present generation. Ramsey (1928), for example, has argued that it is "ethically indefensible" to apply a positive pure rate of time preference to discount values across generations, and many agree with this view.

Other concerns also motivate making adjustments to descriptive discount rates. In particular, it has been noted that the preferences of future generations with regard to consumption versus environmental amenities may not be the same as those today, making the current market rate on consumption an inappropriate metric by which to discount future climate-related damages. Others argue that the discount rate should be below market rates to correct for market distortions and uncertainties or inefficiencies in intergenerational transfers of wealth, which in the Kaldor-Hicks logic are presumed to compensate future generations for damage (a potentially controversial assumption, as noted above; Arrow *et al*. 1996, Weitzman 1999).

Further, a legitimate concern about both descriptive and prescriptive approaches is that they tend to obscure important heterogeneity in the population. The utility function that underlies the prescriptive approach assumes a representative agent with perfect foresight and no credit constraints. This is an artificial rendering of the real world that misses many of the frictions that characterize individuals' lives and indeed the available descriptive evidence supports this. For instance, many individuals smooth consumption by borrowing with credit cards that have relatively high rates. Some are unable to access traditional credit markets and rely on payday lending operations or other high cost forms of smoothing consumption. Whether one puts greater weight on the prescriptive or descriptive approach, the high interest rates that credit-constrained individuals accept suggest that some account should be given to the discount rates revealed by their behavior.

We draw on both approaches but rely primarily on the descriptive approach to inform the choice of discount rate. With recognition of its limitations, we find this approach to be the most defensible and transparent given its consistency with the standard contemporary theoretical foundations of benefit-cost analysis and with the approach required by OMB's existing guidance. The logic of this framework also suggests that market rates should be used for discounting future consumption-equivalent damages. Regardless of the theoretical approach used to derive the appropriate discount rate(s), we note the inherent conceptual and practical difficulties of adequately capturing consumption trade-offs over many decades or even centuries. While relying primarily on the descriptive approach in selecting specific discount rates, the interagency group has been keenly aware of the deeply normative dimensions of both the debate over discounting in the intergenerational context and the consequences of selecting one discount rate over another.

14A.4.6.1 Historically Observed Interest Rates

In a market with no distortions, the return to savings would equal the private return on investment, and the market rate of interest would be the appropriate choice for the social discount rate. In the real world risk, taxes, and other market imperfections drive a wedge between the risk-free rate of return on capital and the consumption rate of interest. Thus, the literature recognizes two conceptual discount concepts—the consumption rate of interest and the opportunity cost of capital.

According to OMB's Circular A-4, it is appropriate to use the rate of return on capital when a regulation is expected to displace or alter the use of capital in the private sector. In this case, OMB recommends Agencies use a discount rate of 7 percent. When regulation is expected to primarily affect private consumption—for instance, via higher prices for goods and services—a lower discount rate of 3 percent is appropriate to reflect how private individuals trade-off current and future consumption.

The interagency group examined the economics literature and concluded that the consumption rate of interest is the correct concept to use in evaluating the benefits and costs of a marginal change in carbon emissions (Lind 1990, Arrow *et al*., 1996, Arrow 2000). The consumption rate of interest also is appropriate when the impacts of a regulation are measured in consumption (-equivalent) units, as is done in the three integrated assessment models used for estimating the SCC.

Individuals use a variety of savings instruments that vary with risk level, time horizon, and tax characteristics. The standard analytic framework used to develop intuition about the discount rate typically assumes a representative agent with perfect foresight and no credit constraints. The risk-free rate is appropriate for discounting certain future benefits or costs, but the benefits calculated by IAMs are uncertain. To use the risk-free rate to discount uncertain benefits, these benefits first must be transformed into "certainty equivalents," *i.e.*, the maximum certain amount that we would exchange for the uncertain amount. However, the calculation of the certainty-equivalent requires first estimating the correlation between the benefits of the policy and baseline consumption.

If the IAM projections of future impacts represent expected values (not certainty-equivalent values), then the appropriate discount rate generally does not equal the risk-free rate. If the benefits of the policy tend to be high in those states of the world in which consumption is low, then the certainty-equivalent benefits will be higher than the expected benefits (and vice versa). Since many (though not necessarily all) of the important impacts of climate change will flow through market sectors such as agriculture and energy, and since willingness to pay for environmental protections typically increases with income, we might expect a positive (though not necessarily perfect) correlation between the net benefits from climate policies and market returns. This line of reasoning suggests that the proper discount rate would exceed the riskless rate. Alternatively, a negative correlation between the returns to climate policies and market returns would imply that a discount rate below the riskless rate is appropriate.

This discussion suggests that both the post-tax riskless and risky rates can be used to capture individuals' consumption-equivalent interest rate. As a measure of the post-tax riskless rate, we calculate the average real return from Treasury notes over the longest time period available (those from Newell and Pizer 2003) and adjust for Federal taxes (the average marginal rate from tax years 2003 through 2006 is around 27 percent).[q] This calculation produces a real interest rate of about 2.7 percent, which is roughly consistent with Circular A-4's recommendation to use 3 percent to represent the consumption rate of interest.[r] A measure of the post-tax risky rate for investments whose returns are positively correlated with overall equity market returns can be obtained by adjusting pre-tax rates of household returns to risky investments (approximately 7 percent) for taxes yields a real rate of roughly 5 percent.[s]

14A.4.6.2 The Ramsey Equation

Ramsey discounting also provides a useful framework to inform the choice of a discount rate. Under this approach, the analyst applies either positive or normative judgments in selecting values for the key parameters of the Ramsey equation: η (coefficient of relative risk aversion or

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[q] The literature argues for a risk-free rate on government bonds as an appropriate measure of the consumption rate of interest. Arrow (2000) suggests that it is roughly 3-4 percent. OMB cites evidence of a 3.1 percent pre-tax rate for 10-year Treasury notes in the A-4 guidance. Newell and Pizer (2003) find real interest rates between 3.5 and 4 percent for 30-year Treasury securities.
[r] The positive approach reflects how individuals make allocation choices across time, but it is important to keep in mind that we wish to reflect preferences for society as a whole, which generally has a longer planning horizon.
[s] Cambell *et al*. (2001) estimates that the annual real return from stocks for 1900-1995 was about 7 percent. The annual real rate of return for the S&P 500 from 1950–2008 was about 6.8 percent. In the absence of a better way to population-weight the tax rates, we use the middle of the 20–40 percent range to derive a post-tax interest rate (Kotlikoff and Rapson 2006).

elasticity of the marginal utility of consumption) and ρ (pure rate of time preference).[t] These are then combined with g (growth rate of per-capita consumption) to equal the interest rate at which future monetized damages are discounted: $\rho + \eta \cdot g$.[u] In the simplest version of the Ramsey model, with an optimizing representative agent with perfect foresight, what we are calling the "Ramsey discount rate," $\rho + \eta \cdot g$, will be equal to the rate of return to capital, *i.e.*, the market interest rate.

A review of the literature provides some guidance on reasonable parameter values for the Ramsey discounting equation, based on both prescriptive and descriptive approaches.

- η. Most papers in the climate change literature adopt values for η in the range of 0.5 to 3 (Weitzman cites plausible values as those ranging from 1 to 4), although not all authors articulate whether their choice is based on prescriptive or descriptive reasoning.[v] Dasgupta (2008) argues that η should be greater than 1 and may be as high as 3, since η equal to 1 suggests savings rates that do not conform to observed behavior.

- ρ. With respect to the pure rate of time preference, most papers in the climate change literature adopt values for ρ in the range of 0 to 3 percent per year. The very low rates tend to follow from moral judgments involving intergenerational neutrality. Some have argued that to use any value other than $\rho = 0$ would unjustly discriminate against future generations (*e.g.*, Arrow *et al*. 1996, Stern 2006). However, even in an inter-generational setting, it may make sense to use a small positive pure rate of time preference because of the small probability of unforeseen cataclysmic events (Stern 2006).

- g. A commonly accepted approximation is around 2 percent per year. For the socio-economic scenarios used for this exercise, the EMF models assume that g is about 1.5–2 percent to 2100.

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[t] The parameter ρ measures the *pure rate of time preference*: people's behavior reveals a preference for an increase in utility today versus the future. Consequently, it is standard to place a lower weight on utility in the future. The parameter η captures *diminishing marginal utility*: consumption in the future is likely to be higher than consumption today, so diminishing marginal utility of consumption implies that the same monetary damage will cause a smaller reduction of utility for wealthier individuals, either in the future or in current generations. If $\eta = 0$, then a one dollar increase in income is equally valuable regardless of level of income; if $\eta = 1$, then a one percent increase in income is equally valuable no matter the level of income; and if $\eta > 1$, then a one percent increase in income is less valuable to wealthier individuals.

[u] In this case, g could be taken from the selected EMF socioeconomic scenarios or alternative assumptions about the rate of consumption growth.

[v] Empirical estimates of η span a wide range of values. A benchmark value of 2 is near the middle of the range of values estimated or used by Szpiro (1986), Hall and Jones (2007), Arrow (2007), Dasgupta (2006, 2008), Weitzman (2007, 2009), and Nordhaus (2008). However, Chetty (2006) developed a method of estimating η using data on labor supply behavior. He shows that existing evidence of the effects of wage changes on labor supply imposes a tight upper bound on the curvature of utility over wealth (CRRA < 2) with the mean implied value of 0.71 and concludes that the standard expected utility model cannot generate high levels of risk aversion without contradicting established facts about labor supply. Recent work has jointly estimated the components of the Ramsey equation. Evans and Sezer (2005) estimate $\eta = 1.49$ for 22 OECD countries. They also estimate $\rho = 1.08$ percent per year using data on mortality rates. Anthoff *et al*. (2009b) estimate $\eta = 1.18$, and $\rho = 1.4$ percent. When they multiply the bivariate probability distributions from their work and Evans and Sezer (2005) together, they find $\eta = 1.47$, and $\rho = 1.07$.

Some economists and non-economists have argued for constant discount rates below 2 percent based on the prescriptive approach. When grounded in the Ramsey framework, proponents of this approach have argued that a ρ of zero avoids giving preferential treatment to one generation over another. The choice of η has also been posed as an ethical choice linked to the value of an additional dollar in poorer countries compared to wealthier ones. Stern (2006) applies this perspective through his choice of ρ = 0.1 percent per year, η = 1 and g = 1.3 percent per year, which yields an annual discount rate of 1.4 percent. In the context of permanent income savings behavior, however, Stern's assumptions suggest that individuals would save 93 percent of their income.[w]

Recently, Stern (2008) revisited the values used in Stern (2006), stating that there is a case to be made for raising η due to the amount of weight lower values place on damages far in the future (over 90 percent of expected damages occur after 2200 with η = 1). Using Stern's assumption that ρ = 0.1 percent, combined with a η of 1.5 to 2 and his original growth rate, yields a discount rate greater 2 percent.

We conclude that arguments made under the prescriptive approach can be used to justify discount rates between roughly 1.4 and 3.1 percent. In light of concerns about the most appropriate value for η, we find it difficult to justify rates at the lower end of this range under the Ramsey framework.

14A.4.6.3 Accounting for Uncertainty in the Discount Rate

While the consumption rate of interest is an important driver of the benefits estimate, it is uncertain over time. Ideally, we would formally model this uncertainty, just as we do for climate sensitivity. Weitzman (1998, 2001) showed theoretically and Newell and Pizer (2003) and Panipoulou *et al.* (2004) confirm empirically that discount rate uncertainty can have a large effect on net present values. A main result from these studies is that if there is a persistent element to the uncertainty in the discount rate (*e.g.*, the rate follows a random walk), then it will result in an effective (or certainty-equivalent) discount rate that declines over time. Consequently, lower discount rates tend to dominate over the very long term (Weitzman 1998, 1999, 2001; Newell and Pizer 2003; Panipoulou *et al.* (2004); Gollier 2008; Summers and Zeckhauser 2008; and Gollier and Weitzman 2009).

The proper way to model discount rate uncertainty remains an active area of research. Newell and Pizer (2003) employ a model of how long-term interest rates change over time to forecast future discount rates. Their model incorporates some of the basic features of how interest rates move over time, and its parameters are estimated based on historical observations of long-term rates. Subsequent work on this topic, most notably Panipoulou *et al.* (2004), uses more general models of interest rate dynamics to allow for better forecasts. Specifically, the volatility of interest rates depends on whether rates are currently low or high and variation in the level of persistence over time.

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[w] Stern (2008) argues that building in a positive rate of exogenous technical change over time reduces the implied savings rate and that η at or above 2 are inconsistent with observed behavior with regard to equity. (At the same time, adding exogenous technical change—all else equal—would increase g as well.)

While Newell and Pizer (2003) and Panipoulou *et al.* (2004) attempt formally to model uncertainty in the discount rate, others argue for a declining scale of discount rates applied over time (*e.g.*, Weitzman 2001, and the UK's "Green Book" for regulatory analysis). This approach uses a higher discount rate initially, but applies a graduated scale of lower discount rates further out in time.[x] A key question that has emerged with regard to both of these approaches is the trade-off between potential time inconsistency and giving greater weight to far future outcomes (see the EPA Science Advisory Board's recent comments on this topic as part of its review of their *Guidelines for Economic Analysis*).[y]

14A.4.6.4 The Discount Rates Selected for Estimating SCC

In light of disagreement in the literature on the appropriate market interest rate to use in this context and uncertainty about how interest rates may change over time, we use three discount rates to span a plausible range of certainty-equivalent constant discount rates: 2.5, 3, and 5 percent per year. Based on the review in the previous sections, the interagency workgroup determined that these three rates reflect reasonable judgments under both descriptive and prescriptive approaches.

The central value (3 percent) is consistent with estimates provided in the economics literature and OMB's Circular A-4 guidance for the consumption rate of interest. As previously mentioned, the consumption rate of interest is the correct discounting concept to use when future damages from elevated temperatures are estimated in consumption-equivalent units. Further, 3 percent roughly corresponds to the after-tax riskless interest rate. The upper value of 5 percent is included to represent the possibility that climate damages are positively correlated with market returns. Additionally, this discount rate may be justified by the high interest rates that many consumers use to smooth consumption across periods.

The low value (2.5 percent) is included to incorporate the concern that interest rates are highly uncertain over time. It represents the average certainty-equivalent rate using the mean-reverting and random walk approaches from Newell and Pizer (2003) starting at a discount rate of 3 percent. Using this approach, the certainty equivalent is about 2.2 percent using the random walk model and 2.8 percent using the mean reverting approach.[z] Without giving preference to a particular model, the average of the two rates is 2.5 percent. Further, a rate below the riskless rate would be justified if climate investments are negatively correlated with the overall market rate of return. Use of this lower value also responds to certain judgments using the prescriptive or normative approach and to ethical objections that have been raised about rates of 3 percent or higher.

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[x] For instance, the UK applies a discount rate of 3.5 percent to the first 30 years; 3 percent for years 31–75; 2.5 percent for years 76–125; 2 percent for years 126–200; 1.5 percent for years 201–300; and 1 percent after 300 years. As a sensitivity, it recommends a discount rate of 3 percent for the first 30 years, also decreasing over time.
[y] Uncertainty in future damages is distinct from uncertainty in the discount rate. Weitzman (2008) argues that Stern's choice of a low discount rate was "right for the wrong reasons." He demonstrates how the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. Newbold and Daigneault, (2009) and Nordhaus (2009) find that Weitzman's result is sensitive to the functional forms chosen for climate sensitivity, utility, and consumption. Summers and Zeckhauser (2008) argue that uncertainty in future damages can also work in the other direction by increasing the benefits of waiting to learn the appropriate level of mitigation required.
[z] Calculations done by Pizer *et al*. using the original simulation program from Newell and Pizer (2003).

14A.5 REVISED SCC ESTIMATES

Our general approach to estimating SCC values is to run the three integrated assessment models (FUND, DICE, and PAGE) using the following inputs agreed upon by the interagency group:

- A Roe and Baker distribution for the climate sensitivity parameter bounded between 0 and 10 with a median of 3 °C and a cumulative probability between 2 and 4.5 °C of two-thirds.
- Five sets of GDP, population and carbon emissions trajectories based on EMF-22.
- Constant annual discount rates of 2.5, 3, and 5 percent.

Because the climate sensitivity parameter is modeled probabilistically, and because PAGE and FUND incorporate uncertainty in other model parameters, the final output from each model run is a distribution over the SCC in year *t*.

For each of the IAMS, the basic computational steps for calculating the SCC in a particular year *t* are:

1. Input the path of emissions, GDP, and population from the selected EMF-22 scenarios, and the extrapolations based on these scenarios for post-2100 years.

2. Calculate the temperature effects and (consumption-equivalent) damages in each year resulting from the baseline path of emissions.

    a. In PAGE, the consumption-equivalent damages in each period are calculated as a fraction of the EMF GDP forecast, depending on the temperature in that period relative to the pre-industrial average temperature in each region.

    b. In FUND, damages in each period depend on both the level and the rate of temperature change in that period.

    c. In DICE, temperature affects both consumption and investment, so we first adjust the EMF GDP paths as follows: Using the Cobb-Douglas production function with the DICE2007 parameters, we extract the path of exogenous technical change implied by the EMF GDP and population paths, then we recalculate the baseline GDP path taking into account climate damages resulting from the baseline emissions path.

3. Add an additional unit of carbon emissions in year *t*. (The exact unit varies by model.)

4. Recalculate the temperature effects and damages expected in all years beyond *t* resulting from this adjusted path of emissions, as in step 2.

5. Subtract the damages computed in step 2 from those in step 4 in each year. (DICE is run in 10 year time steps, FUND in annual time steps, while the time steps in PAGE vary.)

6. Discount the resulting path of marginal damages back to the year of emissions using the agreed upon fixed discount rates.

7. Calculate the SCC as the net present value of the discounted path of damages computed in step 6, divided by the unit of carbon emissions used to shock the models in step 3.

8. Multiply by 12/44 to convert from dollars per ton of carbon to dollars per ton of CO_2 (2007 dollars) in DICE and FUND. (All calculations are done in tons of CO_2 in PAGE).

The steps above were repeated in each model for multiple future years to cover the time horizons anticipated for upcoming rulemaking analysis. To maintain consistency across the three IAMs, climate damages are calculated as lost consumption in each future year.

It is important to note that each of the three models has a different default end year. The default time horizon is 2200 for PAGE, 2595 for DICE, and 3000 for the latest version of FUND. This is an issue for the multi-model approach because differences in SCC estimates may arise simply due to the model time horizon. Many consider 2200 too short a time horizon because it could miss a significant fraction of damages under certain assumptions about the growth of marginal damages and discounting, so each model is run here through 2300. This step required a small adjustment in the PAGE model only. This step also required assumptions about GDP, population, and greenhouse gas emission trajectories after 2100, the last year for which these data are available from the EMF-22 models. (A more detailed discussion of these assumptions is included in the Appendix.)

This exercise produces 45 separate distributions of the SCC for a given year, the product of 3 models, 3 discount rates, and 5 socioeconomic scenarios. This is clearly too many separate distributions for consideration in a regulatory impact analysis.

To produce a range of plausible estimates that still reflects the uncertainty in the estimation exercise, the distributions from each of the models and scenarios are equally weighed and combined to produce three separate probability distributions for SCC in a given year, one for each assumed discount rate. These distributions are then used to define a range of point estimates for the global SCC. In this way, no integrated assessment model or socioeconomic scenario is given greater weight than another. Because the literature shows that the SCC is quite sensitive to assumptions about the discount rate, and because no consensus exists on the appropriate rate to use in an intergenerational context, we present SCCs based on the average values across models and socioeconomic scenarios for each discount rate.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC across models and socio-economic and emissions scenarios at the 2.5, 3, and 5 percent discount rates. The fourth value is included to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. (The full set of distributions by model and scenario combination is included in the Appendix.) As noted above, the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range.

As previously discussed, low probability, high impact events are incorporated into the SCC values through explicit consideration of their effects in two of the three models as well as the use of a probability density function for equilibrium climate sensitivity. Treating climate sensitivity probabilistically results in more high temperature outcomes, which in turn lead to higher projections of damages. Although FUND does not include catastrophic damages (in contrast to the other two models), its probabilistic treatment of the equilibrium climate sensitivity parameter will directly affect the non-catastrophic damages that are a function of the rate of temperature change.

In Table 14A.5.1**,** we begin by presenting SCC estimates for 2010 by model, scenario, and discount rate to illustrate the variability in the SCC across each of these input parameters. As expected, higher discount rates consistently result in lower SCC values, while lower discount rates result in higher SCC values for each socioeconomic trajectory. It is also evident that there are differences in the SCC estimated across the three main models. For these estimates, FUND produces the lowest estimates, while PAGE generally produces the highest estimates.

Table 14A.5.1 Disaggregated Social Cost of CO2 Values by Model, Socio-Economic Trajectory, and Discount Rate for 2010 (2007$)

	Discount rate:	**5%**	**3%**	**2.5%**	**3%**
Model	*Scenario*	Avg	Avg	Avg	95th
DICE	IMAGE	10.8	35.8	54.2	70.8
	MERGE	7.5	22.0	31.6	42.1
	Message	9.8	29.8	43.5	58.6
	MiniCAM	8.6	28.8	44.4	57.9
	550 Average	8.2	24.9	37.4	50.8
PAGE	IMAGE	8.3	39.5	65.5	142.4
	MERGE	5.2	22.3	34.6	82.4
	Message	7.2	30.3	49.2	115.6
	MiniCAM	6.4	31.8	54.7	115.4
	550 Average	5.5	25.4	42.9	104.7
FUND	IMAGE	-1.3	8.2	19.3	39.7
	MERGE	-0.3	8.0	14.8	41.3
	Message	-1.9	3.6	8.8	32.1
	MiniCAM	-0.6	10.2	22.2	42.6
	550 Average	-2.7	-0.2	3.0	19.4

These results are not surprising when compared to the estimates in the literature for the latest versions of each model. For example, adjusting the values from the literature that were used to develop interim SCC values to 2007 dollars for the year 2010 (assuming, as we did for the interim process, that SCC grows at 3 percent per year), FUND yields SCC estimates at or near zero for a 5 percent discount rate and around $9 per ton for a 3 percent discount rate. There are far fewer estimates using the latest versions of DICE and PAGE in the literature: Using similar adjustments to generate 2010 estimates, we calculate a SCC from DICE (based on Nordhaus 2008) of around $9 per ton for a 5 percent discount rate, and a SCC from PAGE (based on Hope 2006, 2008) close to $8 per ton for a 4 percent discount rate. Note that these comparisons are only approximate since the literature generally relies on Ramsey discounting, while we have assumed constant discount rates.[aa]

The SCC estimates from FUND are sensitive to differences in emissions paths but relatively insensitive to differences in GDP paths across scenarios, while the reverse is true for DICE and PAGE. This likely occurs because of several structural differences among the models. Specifically in DICE and PAGE, the fraction of economic output lost due to climate damages increases with the level of temperature alone, whereas in FUND the fractional loss also increases with the rate of temperature change. Further, in FUND increases in income over time decrease vulnerability to climate change (a form of adaptation), whereas this does not occur in DICE and PAGE. These structural differences among the models make FUND more sensitive to the path of emissions and less sensitive to GDP compared to DICE and PAGE.

Figure 14A.5.1 shows that IMAGE has the highest GDP in 2100 while MERGE Optimistic has the lowest. The ordering of global GDP levels in 2100 directly corresponds to the rank ordering of SCC for PAGE and DICE. For FUND, the correspondence is less clear, a result that is to be expected given its less direct relationship between its damage function and GDP.

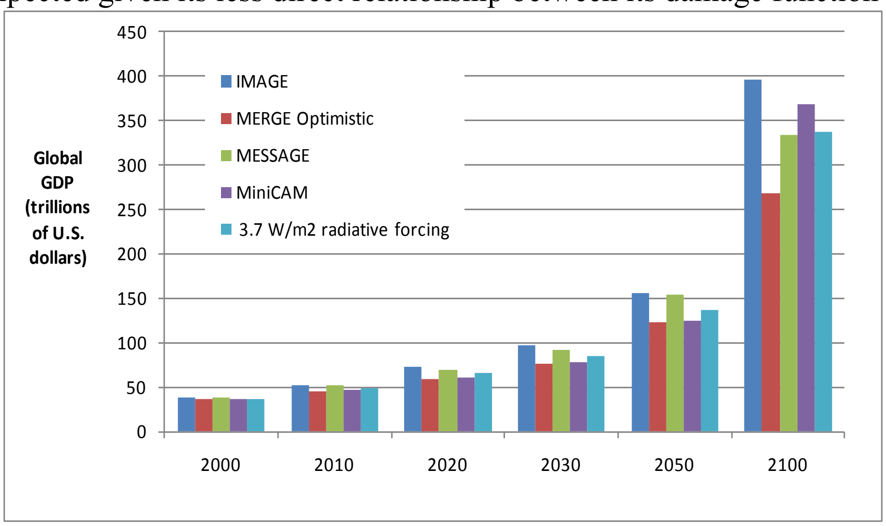

Figure 14A.5.1 Level of Global GDP Across EMF Scenarios

Table 14A.5.2 shows the four selected SCC values in 5-year increments from 2010 to 2050. Values for 2010, 2020, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using a simple linear interpolation.

[aa] Nordhaus (2008) runs DICE2007 with ρ = 1.5 and η = 2. The default approach in PAGE2002 (version 1.4epm) treats ρ and η as random parameters, specified using a triangular distribution such that the min, mode, and max = 0.1, 1, and 2 for ρ, and 0.5, 1, and 2 for η, respectively. The FUND default value for η is 1, and Tol generates SCC estimates for values of ρ = 0, 1, and 3 in many recent papers (*e.g.*, Anthoff *et al*. 2009). The path of per-capita consumption growth, g, varies over time but is treated deterministically in two of the three models. In DICE, g is endogenous. Under Ramsey discounting, as economic growth slows in the future, the large damages from climate change that occur far out in the future are discounted at a lower rate than impacts that occur in the nearer term.

Table 14A.5.2 Social Cost of CO_2, 2010–2050 (2007$)

Discount Rate	5%	3%	2.5%	3%
Year	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2015	5.7	23.8	38.4	72.8
2020	6.8	26.3	41.7	80.7
2025	8.2	29.6	45.9	90.4
2030	9.7	32.8	50.0	100.0
2035	11.2	36.0	54.2	109.7
2040	12.7	39.2	58.4	119.3
2045	14.2	42.1	61.7	127.8
2050	15.7	44.9	65.0	136.2

The SCC increases over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. Note that this approach allows us to estimate the growth rate of the SCC directly using DICE, PAGE, and FUND rather than assuming a constant annual growth rate as was done for the interim estimates (using 3 percent). This helps to ensure that the estimates are internally consistent with other modeling assumptions. Table 14A.5.3 illustrates how the growth rate for these four SCC estimates varies over time. The full set of annual SCC estimates between 2010 and 2050 is reported in the Appendix.

Table 14A.5.3 Changes in the Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Growth Rate	5%	3%	2.5%	3.0%
Year Range	Avg	Avg	Avg	95th
2010–2020	3.6	2.1	1.7	2.2
2020–2030	3.7	2.2	1.8	2.2
2030–2040	2.7	1.8	1.6	1.8
2040–2050	2.1	1.4	1.1	1.3

While the SCC estimate grows over time, the future monetized value of emissions reductions in each year (the SCC in year *t* multiplied by the change in emissions in year *t*) must be discounted to the present to determine its total net present value for use in regulatory analysis. Damages from future emissions should be discounted at the same rate as that used to calculate the SCC estimates themselves to ensure internal consistency—*i.e.*, future damages from climate change, whether they result from emissions today or emissions in a later year, should be discounted using the same rate. For example, climate damages in 2020 that are calculated using a SCC based on a 5 percent discount rate also should be discounted back to the analysis year using a 5 percent discount rate.[bb]

14A.6 LIMITATIONS OF THE ANALYSIS

As noted, any estimate of the SCC must be taken as provisional and subject to further refinement (and possibly significant change) in accordance with evolving scientific, economic, and ethical understandings. During the course of our modeling, it became apparent that there are

[bb] However, it is possible that other benefits or costs of proposed regulations unrelated to CO_2 emissions will be discounted at rates that differ from those used to develop the SCC estimates.

several areas in particular need of additional exploration and research. These caveats and additional observations in the following section are necessary to consider when interpreting and applying the SCC estimates.

Incomplete treatment of non-catastrophic damages. The impacts of climate change are expected to be widespread, diverse, and heterogeneous. In addition, the exact magnitude of these impacts is uncertain because of the inherent complexity of climate processes, the economic behavior of current and future populations, and our inability to accurately forecast technological change and adaptation. Current IAMs do not assign value to all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature (some of which are discussed above) because of lack of precise information on the nature of damages and because the science incorporated into these models understandably lags behind the most recent research. Our ability to quantify and monetize impacts will undoubtedly improve with time. It is also likely that even in future applications, a number of potentially significant damage categories will remain non-monetized. (Ocean acidification is one example of a potentially large damage from CO_2 emissions not quantified by any of the three models. Species and wildlife loss is another example that is exceedingly difficult to monetize.)

Incomplete treatment of potential catastrophic damages. There has been considerable recent discussion of the risk of catastrophic impacts and how best to account for extreme scenarios, such as the collapse of the Atlantic Meridional Overturning Circulation or the West Antarctic Ice Sheet, or large releases of methane from melting permafrost and warming oceans. Weitzman (2009) suggests that catastrophic damages are extremely large—so large, in fact, that the damages from a low probability, catastrophic event far in the future dominate the effect of the discount rate in a present value calculation and result in an infinite willingness-to-pay for mitigation today. However, Nordhaus (2009) concluded that the conditions under which Weitzman's results hold "are limited and do not apply to a wide range of potential uncertain scenarios."

Using a simplified IAM, Newbold and Daigneault (2009) confirmed the potential for large catastrophe risk premiums but also showed that the aggregate benefit estimates can be highly sensitive to the shapes of both the climate sensitivity distribution and the damage function at high temperature changes. Pindyck (2009) also used a simplified IAM to examine high-impact low-probability risks, using a right-skewed gamma distribution for climate sensitivity as well as an uncertain damage coefficient, but in most cases found only a modest risk premium. Given this difference in opinion, further research in this area is needed before its practical significance can be fully understood and a reasonable approach developed to account for such risks in regulatory analysis. (The next section discusses the scientific evidence on catastrophic impacts in greater detail.)

Uncertainty in extrapolation of damages to high temperatures. The damage functions in these IAMs are typically calibrated by estimating damages at moderate temperature increases (*e.g.*, DICE was calibrated at 2.5 °C) and extrapolated to far higher temperatures by assuming that damages increase as some power of the temperature change. Hence, estimated damages are far more uncertain under more extreme climate change scenarios.

Incomplete treatment of adaptation and technological change. Each of the three integrated assessment models used here assumes a certain degree of low- or no-cost adaptation. For instance, Tol assumes a great deal of adaptation in FUND, including widespread reliance on air conditioning, so much so that the largest single benefit category in FUND is the reduced electricity costs from not having to run air conditioning as intensively (NRC 2009).

Climate change also will increase returns on investment to develop technologies that allow individuals to cope with adverse climate conditions, and IAMs to do not adequately account for this directed technological change.[cc] For example, scientists may develop crops that are better able to withstand higher and more variable temperatures. Although DICE and FUND have both calibrated their agricultural sectors under the assumption that farmers will change land use practices in response to climate change (Mastrandrea 2009), they do not take into account technological changes that lower the cost of this adaptation over time. On the other hand, the calibrations do not account for increases in climate variability, pests, or diseases, which could make adaptation more difficult than assumed by the IAMs for a given temperature change. Hence, models do not adequately account for potential adaptation or technical change that might alter the emissions pathway and resulting damages. In this respect, it is difficult to determine whether the incomplete treatment of adaptation and technological change in these IAMs under or overstate the likely damages.

Risk aversion. A key question unanswered during this interagency process is what to assume about relative risk aversion with regard to high-impact outcomes. These calculations do not take into account the possibility that individuals may have a higher willingness to pay to reduce the likelihood of low-probability, high-impact damages than they do to reduce the likelihood of higher-probability but lower-impact damages with the same expected cost. (The inclusion of the 95th percentile estimate in the final set of SCC values was largely motivated by this concern.) If individuals do show such a higher willingness to pay, a further question is whether that fact should be taken into account for regulatory policy. Even if individuals are not risk-averse for such scenarios, it is possible that regulatory policy should include a degree of risk-aversion.

Assuming a risk-neutral representative agent is consistent with OMB's Circular A-4, which advises that the estimates of benefits and costs used in regulatory analysis are usually based on the average or the expected value and that "emphasis on these expected values is appropriate as long as society is 'risk neutral' with respect to the regulatory alternatives. While this may not always be the case, [analysts] should in general assume 'risk neutrality' in [their] analysis."

Nordhaus (2008) points to the need to explore the relationship between risk and income in the context of climate change across models and to explore the role of uncertainty regarding various parameters in the results. Using FUND, Anthoff *et al.* (2009) explored the sensitivity of the SCC to Ramsey equation parameter assumptions based on observed behavior. They conclude that "the assumed rate of risk aversion is at least as important as the assumed rate of time preference in determining the social cost of carbon." Since Circular A-4 allows for a different

[cc] However these research dollars will be diverted from whatever their next best use would have been in the absence of climate change (so productivity/GDP would have been still higher).

assumption on risk preference in regulatory analysis if it is adequately justified, we plan to continue investigating this issue.

14A.7 A FURTHER DISCUSSION OF CATASTROPHIC IMPACTS AND DAMAGE FUNCTIONS

As noted above, the damage functions underlying the three IAMs used to estimate the SCC may not capture the economic effects of all possible adverse consequences of climate change and may therefore lead to underestimates of the SCC (Mastrandrea 2009). In particular, the models' functional forms may not adequately capture: (1) potentially discontinuous "tipping point" behavior in Earth systems; (2) inter-sectoral and inter-regional interactions, including global security impacts of high-end warming; and (3) limited near-term substitutability between damage to natural systems and increased consumption.

It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling. In the meantime, we discuss some of the available evidence.

14A.7.1 Extrapolation of Climate Damages to High Levels of Warming

The damage functions in the models are calibrated at moderate levels of warming and should therefore be viewed cautiously when extrapolated to the high temperatures found in the upper end of the distribution. Recent science suggests that there are a number of potential climatic "tipping points" at which the Earth system may exhibit discontinuous behavior with potentially severe social and economic consequences (*e.g.*, Lenton *et al.* 2008, Kriegler *et al.* 2009). These tipping points include the disruption of the Indian Summer Monsoon, dieback of the Amazon Rainforest and boreal forests, collapse of the Greenland Ice Sheet and the West Antarctic Ice Sheet, reorganization of the Atlantic Meridional Overturning Circulation, strengthening of El Niño-Southern Oscillation, and the release of methane from melting permafrost. Many of these tipping points are estimated to have thresholds between about 3 °C and 5 °C (Lenton *et al.* 2008). Probabilities of several of these tipping points were assessed through expert elicitation in 2005–2006 by Kriegler *et al.* (2009); results from this study are highlighted in Table 14A.7.1. Ranges of probability are averaged across core experts on each topic.

Table 14A.7.1 Probabilities of Various Tipping Points from Expert Elicitation

Possible Tipping Points	Duration before effect is fully realized	Additional Warming by 2100 %		
	years	**0.5–1.5 C**	**1.5–3.0 C**	**3–5 C**
Reorganization of Atlantic Meridional Overturning Circulation	about 100	0–18	6–39	18–67
Greenland Ice Sheet Collapse	at least 300	8–39	33–73	67–96
West Antarctic Ice Sheet Collapse	at least 300	5–41	10–63	33–88
Dieback of Amazon rainforest	about 50	2–46	14–84	41–94
Strengthening of El Niño-Southern Oscillation	about 100	1–13	6–32	19–49
Dieback of Boreal Forests	about 50	13–43	20–81	34–91
Shift in Indian Summer Monsoon	about 1	not formally assessed		
Release of Methane from Melting Permafrost	less than 100	not formally assessed		

As previously mentioned, FUND does not include potentially catastrophic effects. DICE assumes a small probability of catastrophic damages that increases with increased warming, but the damages from these risks are incorporated as expected values (*i.e.*, ignoring potential risk aversion). PAGE models catastrophic impacts in a probabilistic framework (Figure 14-A.4.1), so the high-end output from PAGE potentially offers the best insight into the SCC if the world were to experience catastrophic climate change. For instance, at the 95^{th} percentile and a 3 percent discount rate, the SCC estimated by PAGE across the five socio-economic and emission trajectories of $113 per ton of CO_2 is almost double the value estimated by DICE, $58 per ton in 2010. We cannot evaluate how well the three models account for catastrophic or non-catastrophic impacts, but this estimate highlights the sensitivity of SCC values in the tails of the distribution to the assumptions made about catastrophic impacts.

PAGE treats the possibility of a catastrophic event probabilistically, while DICE treats it deterministically (*i.e.*, by adding the expected value of the damage from a catastrophe to the aggregate damage function). In part, this results in different probabilities being assigned to a catastrophic event across the two models. For instance, PAGE places a probability near zero on a catastrophe at 2.5 °C warming, while DICE assumes a 4 percent probability of a catastrophe at 2.5 °C. By comparison, Kriegler *et al.* (2009) estimate a probability of at least 16–36 percent of crossing at least one of their primary climatic tipping points in a scenario with temperatures about 2–4 °C warmer than pre-Industrial levels in 2100.

It is important to note that crossing a climatic tipping point will not necessarily lead to an economic catastrophe in the sense used in the IAMs. A tipping point is a critical threshold across which some aspect of the Earth system starts to shifts into a qualitatively different state (for instance, one with dramatically reduced ice sheet volumes and higher sea levels). In the IAMs, a catastrophe is a low-probability environmental change with high economic impact.

14A.7.2 Failure to Incorporate Inter-Sectoral and Inter-Regional Interactions

The damage functions do not fully incorporate either inter-sectoral or inter-regional interactions. For instance, while damages to the agricultural sector are incorporated, the effects of changes in food supply on human health are not fully captured and depend on the modeler's choice of studies used to calibrate the IAM. Likewise, the effects of climate damages in one region of the world on another region are not included in some of the models (FUND includes the effects of migration from sea level rise). These inter-regional interactions, though difficult to quantify, are the basis for climate-induced national and economic security concerns (*e.g.*, Campbell *et al.* 2007; U.S. Department of Defense 2010) and are particularly worrisome at higher levels of warming. High-end warming scenarios, for instance, project water scarcity affecting 4.3–6.9 billion people by 2050, food scarcity affecting about 120 million additional people by 2080, and the creation of millions of climate refugees (Easterling *et al.* 2007; Campbell *et al*. 2007).

14A.7.3 Imperfect Substitutability of Environmental Amenities

Data from the geological record of past climate changes suggests that 6 °C of warming may have severe consequences for natural systems. For instance, during the Paleocene-Eocene Thermal Maximum about 55.5 million years ago, when the Earth experienced a geologically rapid release of carbon associated with an approximately 5 °C increase in global mean temperatures, the effects included shifts of about 400–900 miles in the range of plants (Wing *et al.* 2005), and dwarfing of both land mammals (Gingerich 2006) and soil fauna (Smith *et al.* 2009).

The three IAMs used here assume that it is possible to compensate for the economic consequences of damages to natural systems through increased consumption of non-climate goods, a common assumption in many economic models. In the context of climate change, however, it is possible that the damages to natural systems could become so great that no increase in consumption of non-climate goods would provide complete compensation (Levy *et al.* 2005). For instance, as water supplies become scarcer or ecosystems become more fragile and less bio-diverse, the services they provide may become increasingly more costly to replace. Uncalibrated attempts to incorporate the imperfect substitutability of such amenities into IAMs (Sterner and Persson 2008) indicate that the optimal degree of emissions abatement can be considerably greater than is commonly recognized.

14A.8 CONCLUSION

The interagency group selected four SCC estimates for use in regulatory analyses. For 2010, these estimates are $4.7, $21.4, $35.1, and $64.9 (2007$). The first three estimates are based on the average SCC across models and socio-economic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, we use the SCC value for the 95th percentile at a 3 percent discount rate. The central value is the average SCC across models at the 3 percent discount rate. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range. These SCC estimates also grow over time. For instance, the central value increases to $24 per ton of CO_2 in 2015 and $26 per ton of CO_2 in 2020.

We noted a number of limitations to this analysis, including the incomplete way in which the integrated assessment models capture catastrophic and non-catastrophic impacts, their incomplete treatment of adaptation and technological change, uncertainty in the extrapolation of damages to high temperatures, and assumptions regarding risk aversion. The limited amount of research linking climate impacts to economic damages makes this modeling exercise even more difficult. It is the hope of the interagency group that over time researchers and modelers will work to fill these gaps and that the SCC estimates used for regulatory analysis by the Federal government will continue to evolve with improvements in modeling.

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14A.10 ANNEX

This Annex provides additional technical information about the non-CO_2 emission projections used in the modeling and the method for extrapolating emissions forecasts through 2300, and shows the full distribution of 2010 SCC estimates by model and scenario combination. Annual SCC values for the next 40 years are provided in Table 14A.9.1.

Table 14A.9.1 Annual SCC Values: 2010–2050 (2007$)

Discount Rate	5%	3%	2.5%	3%
Year	Avg	Avg	Avg	95th
2010	4.7	21.4	35.1	64.9
2011	4.9	21.9	35.7	66.5
2012	5.1	22.4	36.4	68.1
2013	5.3	22.8	37.0	69.6
2014	5.5	23.3	37.7	71.2
2015	5.7	23.8	38.4	72.8
2016	5.9	24.3	39.0	74.4
2017	6.1	24.8	39.7	76.0
2018	6.3	25.3	40.4	77.5
2019	6.5	25.8	41.0	79.1
2020	6.8	26.3	41.7	80.7
2021	7.1	27.0	42.5	82.6
2022	7.4	27.6	43.4	84.6
2023	7.7	28.3	44.2	86.5
2024	7.9	28.9	45.0	88.4
2025	8.2	29.6	45.9	90.4
2026	8.5	30.2	46.7	92.3
2027	8.8	30.9	47.5	94.2
2028	9.1	31.5	48.4	96.2
2029	9.4	32.1	49.2	98.1
2030	9.7	32.8	50.0	100.0
2031	10.0	33.4	50.9	102.0
2032	10.3	34.1	51.7	103.9
2033	10.6	34.7	52.5	105.8
2034	10.9	35.4	53.4	107.8
2035	11.2	36.0	54.2	109.7
2036	11.5	36.7	55.0	111.6
2037	11.8	37.3	55.9	113.6
2038	12.1	37.9	56.7	115.5
2039	12.4	38.6	57.5	117.4
2040	12.7	39.2	58.4	119.3
2041	13.0	39.8	59.0	121.0
2042	13.3	40.4	59.7	122.7
2043	13.6	40.9	60.4	124.4
2044	13.9	41.5	61.0	126.1
2045	14.2	42.1	61.7	127.8
2046	14.5	42.6	62.4	129.4
2047	14.8	43.2	63.0	131.1
2048	15.1	43.8	63.7	132.8
2049	15.4	44.4	64.4	134.5
2050	15.7	44.9	65.0	136.2

14A.10.1 Other (non-CO_2) Gases

In addition to fossil and industrial CO_2 emissions, each EMF scenario provides projections of methane (CH_4), nitrous oxide (N_2O), fluorinated gases, and net land use CO_2 emissions to 2100. These assumptions are used in all three IAMs while retaining each model's default radiative forcings (RF) due to other factors (*e.g.*, aerosols and other gases). Specifically, to obtain the RF associated with the non-CO_2 EMF emissions only, we calculated the RF associated with the EMF atmospheric CO_2 concentrations and subtracted them from the EMF total RF.[dd] This approach respects the EMF scenarios as much as possible and at the same time takes account of those components not included in the EMF projections. Since each model treats non-CO_2 gases differently (*e.g.*, DICE lumps all other gases into one composite exogenous input), this approach was applied slightly differently in each of the models.

<u>FUND</u>: Rather than relying on RF for these gases, the actual emissions from each scenario were used in FUND. The model default trajectories for CH_4, N_2O, SF_6, and the CO_2 emissions from land were replaced with the EMF values.

<u>PAGE</u>: PAGE models CO_2, CH_4, sulfur hexafluoride (SF_6), and aerosols and contains an "excess forcing" vector that includes the RF for everything else. To include the EMF values, we removed the default CH_4 and SF_6 factors,[ee] decomposed the excess forcing vector, and constructed a new excess forcing vector that includes the EMF RF for CH_4, N_2O, and fluorinated gases, as well as the model default values for aerosols and other factors. Net land use CO_2 emissions were added to the fossil and industrial CO_2 emissions pathway.

<u>DICE</u>: DICE presents the greatest challenge because all forcing due to factors other than industrial CO_2 emissions is embedded in an exogenous non-CO_2 RF vector. To decompose this exogenous forcing path into EMF non-CO_2 gases and other gases, we relied on the references in DICE2007 to the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report (AR4) and the discussion of aerosol forecasts in the IPCC's Third Assessment Report (TAR) and in AR4, as explained below. In DICE2007, Nordhaus assumes that exogenous forcing from all non-CO_2 sources is -0.06 W/m^2 in 2005, as reported in AR4, and increases linearly to 0.3 W/m^2 in 2105, based on GISS projections, and then stays constant after that time.

According to AR4, the RF in 2005 from CH_4, N_20, and halocarbons (approximately similar to the F-gases in the EMF-22 scenarios) was $0.48 + 0.16 + 0.34 = 0.98$ W/m^2 and RF from total aerosols was -1.2 W/m^2. Thus, the -.06 W/m^2 non-CO_2 forcing in DICE can be decomposed into: 0.98 W/m^2 due to the EMF non-CO_2 gases, -1.2 W/m^2 due to aerosols, and the remainder, 0.16 W/m^2, due to other residual forcing.

[dd] Note EMF did not provide CO_2 concentrations for the IMAGE reference scenario. Thus, for this scenario, we fed the fossil, industrial and land CO_2 emissions into MAGICC (considered a "neutral arbiter" model, which is tuned to emulate the major global climate models) and the resulting CO_2 concentrations were used. Note also that MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (*i.e.*, we add up the land use emissions from the other three models and divide by 4).
[ee] Both the model default CH_4 emissions and the initial atmospheric CH_4 is set to zero to avoid double counting the effect of past CH_4 emissions.

For subsequent years, we calculated the DICE default RF from aerosols and other non-CO_2 gases based on the following two assumptions:

(1) RF from aerosols declines linearly from 2005 to 2100 at the rate projected by the TAR and then stays constant thereafter, and

(2) With respect to RF from non-CO_2 gases not included in the EMF-22 scenarios, the share of non-aerosol RF matches the share implicit in the AR4 summary statistics cited above and remains constant over time.

Assumption (1) means that the RF from aerosols in 2100 equals 66 percent of that in 2000, which is the fraction of the TAR projection of total RF from aerosols (including sulfates, black carbon, and organic carbon) in 2100 vs. 2000 under the A1B SRES emissions scenario. Since the SRES marker scenarios were not updated for the AR4, the TAR provides the most recent IPCC projection of aerosol forcing. We rely on the A1B projection from the TAR because it provides one of the lower aerosol forecasts among the SRES marker scenarios and is more consistent with the AR4 discussion of the post-SRES literature on aerosols:

> Aerosols have a net cooling effect and the representation of aerosol and aerosol precursor emissions, including sulphur dioxide, black carbon and organic carbon, has improved in the post-SRES scenarios. Generally, these emissions are projected to be lower than reported in SRES. {WGIII 3.2, TS.3, SPM}.[ff]

Assuming a simple linear decline in aerosols from 2000 to 2100 also is more consistent with the recent literature on these emissions. For example, Figure 17A.9.1 shows that the sulfur dioxide emissions peak over the short-term of some SRES scenarios above the upper bound estimates of the more recent scenarios.[gg] Recent scenarios project sulfur emissions to peak earlier and at lower levels compared to the SRES in part because of new information about present and planned sulfur legislation in some developing countries, such as India and China.[hh] The lower bound projections of the recent literature have also shifted downward slightly compared to the SRES scenario (IPCC 2007).

With these assumptions, the DICE aerosol forcing changes from -1.2 in 2005 to -0.792 in 2105 W/m^2; forcing due to other non-CO_2 gases not included in the EMF scenarios declines from 0.160 to 0.153 W/m^2.

[ff] AR4 Synthesis Report, p. 44, http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf

[gg] See Smith, S.J., R. Andres, E. Conception, and J. Lurz. 2004. "Historical sulfur dioxide emissions, 1850-2000: methods and results." Joint Global Research Institute, College Park, 14 pp.

[hh] See Carmichael, G., D. Streets, G. Calori, M. Amann, M. Jacobson, J. Hansen, and H. Ueda. 2002. "Changing trends in sulphur emissions in Asia: implications for acid deposition, air pollution, and climate." *Environmental Science and Technology* 36(22):4707- 4713; Streets, D., K. Jiang, X. Hu, J. Sinton, X.-Q. Zhang, D. Xu, M. Jacobson, and J. Hansen. 2001. "Recent reductions in China's greenhouse gas emissions." *Science* 294(5548):1835-1837.

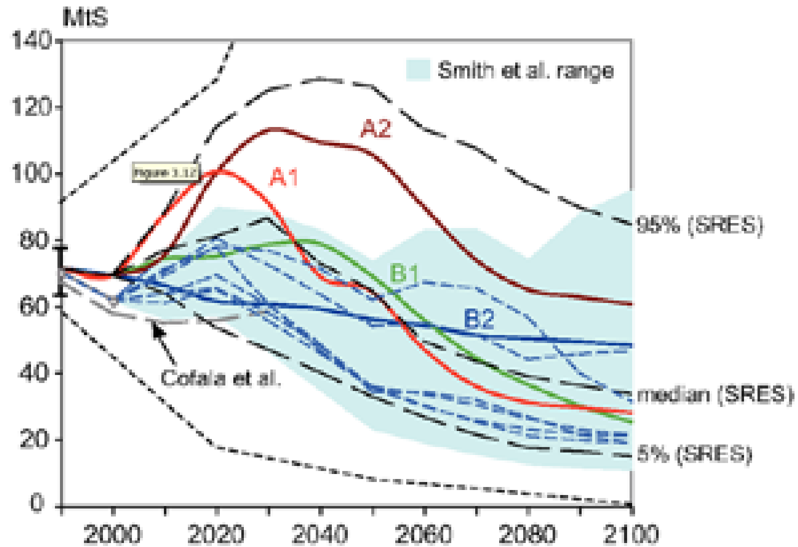

Figure 14A.9.1 Sulphur Dioxide Emission Scenarios

Notes: Thick colored lines depict the four SRES marker scenarios and black dashed lines show the median, 5th and 95th percentile of the frequency distribution for the full ensemble of 40 SRES scenarios. The blue area (and the thin dashed lines in blue) illustrates individual scenarios and the range of Smith *et al.* (2004). Dotted lines indicate the minimum and maximum of SO_2 emissions scenarios developed pre-SRES.
Source: IPCC (2007), AR4 WGIII 3.2, http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch3-ens3-2-2-4.html.

Although other approaches to decomposing the DICE exogenous forcing vector are possible, initial sensitivity analysis suggests that the differences among reasonable alternative approaches are likely to be minor. For example, adjusting the TAR aerosol projection above to assume that aerosols will be maintained at 2000 levels through 2100 reduces average SCC values (for 2010) by approximately 3 percent (or less than $2); assuming all aerosols are phased out by 2100 increases average 2010 SCC values by 6–7 percent (or $0.50–$3), depending on the discount rate. These differences increase slightly for SCC values in later years but are still well within 10 percent of each other as far out as 2050.

Finally, as in PAGE, the EMF net land use CO_2 emissions are added to the fossil and industrial CO_2 emissions pathway.

14A.10.2 Extrapolating Emissions Projections to 2300

To run each model through 2300 requires assumptions about GDP, population, greenhouse gas emissions, and radiative forcing trajectories after 2100, the last year for which these projections are available from the EMF-22 models. These inputs were extrapolated from 2100 to 2300 as follows:

1. Population growth rate declines linearly, reaching zero in 2200.
2. GDP/per capita growth rate declines linearly, reaching zero in 2300.
3. The decline in the fossil and industrial carbon intensity (CO_2/GDP) growth rate over 2090-2100 is maintained from 2100 through 2300.

4. Net land use CO_2 emissions decline linearly, reaching zero in 2200.
5. Non-CO_2 radiative forcing remains constant after 2100.

Long run stabilization of GDP per capita was viewed as a more realistic simplifying assumption than a linear or exponential extrapolation of the pre-2100 economic growth rate of each EMF scenario. This is based on the idea that increasing scarcity of natural resources and the degradation of environmental sinks available for assimilating pollution from economic production activities may eventually overtake the rate of technological progress. Thus, the overall rate of economic growth may slow over the very long run. The interagency group also considered allowing an exponential decline in the growth rate of GDP per capita. However, since this would require an additional assumption about how close to zero the growth rate would get by 2300, the group opted for the simpler and more transparent linear extrapolation to zero by 2300.

The population growth rate is also assumed to decline linearly, reaching zero by 2200. This assumption is reasonably consistent with the United Nations long run population forecast, which estimates global population to be fairly stable after 2150 in the medium scenario (UN 2004).[ii] The resulting range of EMF population trajectories (Figure 14A.9.2) also encompass the UN medium scenario forecasts through 2300 – global population of 8.5 billion by 2200, and 9 billion by 2300.

Maintaining the decline in the 2090–2100 carbon intensity growth rate (*i.e.*, CO_2 per dollar of GDP) through 2300 assumes that technological improvements and innovations in the areas of energy efficiency and other carbon reducing technologies (possibly including currently unavailable methods) will continue to proceed at roughly the same pace that is projected to occur towards the end of the forecast period for each EMF scenario. This assumption implies that total cumulative emissions in 2300 will be between 5,000 and 12,000 GtC, which is within the range of the total potential global carbon stock estimated in the literature.

Net land use CO_2 emissions are expected to stabilize in the long run, so in the absence of any post 2100 projections, the group assumed a linear decline to zero by 2200. Given no a priori reasons for assuming a long run increase or decline in non-CO_2 radiative forcing, it is assumed to remain at the 2100 levels for each EMF scenario through 2300.

Figure 14A.9.2 through Figure 14A.9.8 show the paths of global population, GDP, fossil and industrial CO_2 emissions, net land CO_2 emissions, non-CO_2 radiative forcing, and CO_2 intensity (fossil and industrial CO_2 emissions/GDP) resulting from these assumptions.

[ii] United Nations. 2004. *World Population to 2300*. http://www.un.org/esa/population/publications/longrange2/worldpop2300final.pdf.

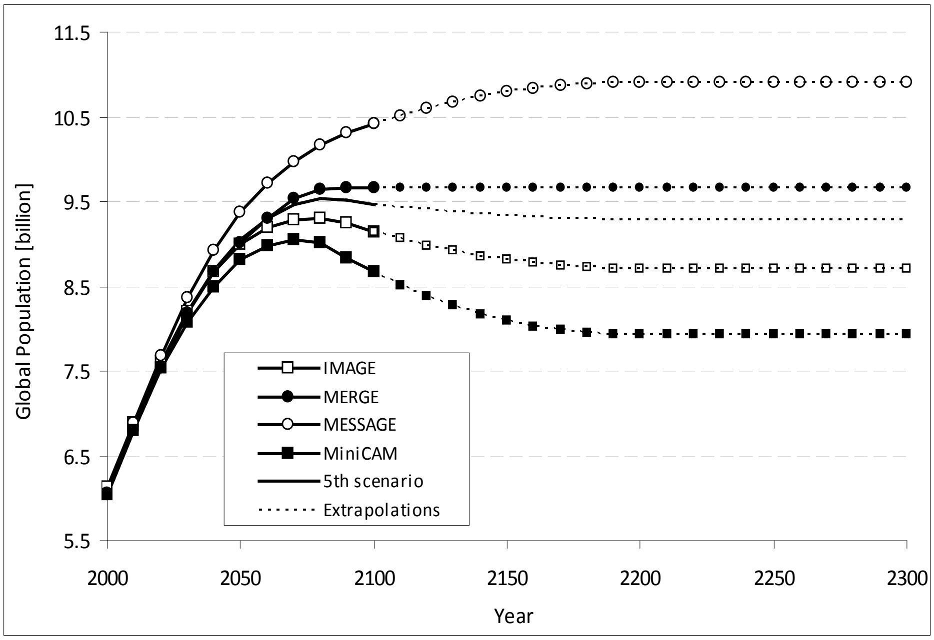

Figure 14A.9.2 Global Population, 2000–2300 (post-2100 extrapolations assume the population growth rate changes linearly to reach a zero growth rate by 2200)

Note: In the fifth scenario, 2000–2100 population is equal to the average of the population under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

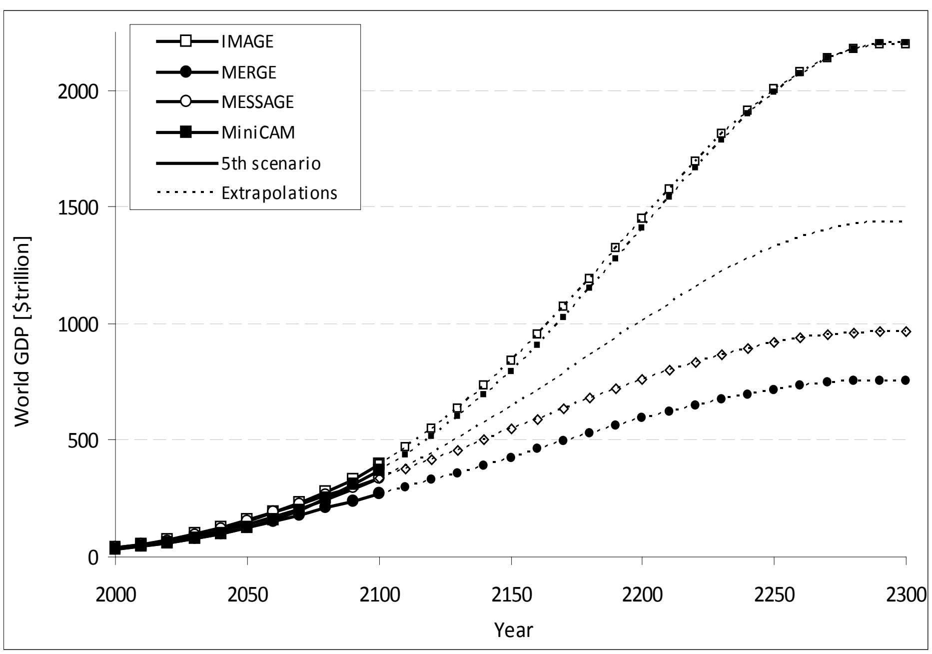

Figure 14A.9.3 World GDP, 2000-2300 (post-2100 extrapolations assume GDP per capita growth declines linearly, reaching zero in 2300)

Note: In the fifth scenario, 2000–2100 GDP is equal to the average of the GDP under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

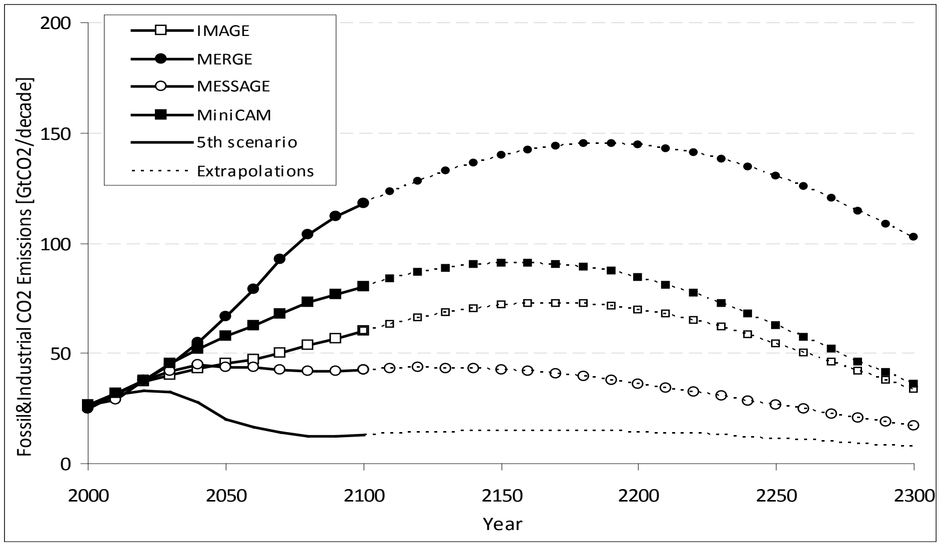

Figure 14A.9.4 Global Fossil and Industrial CO_2 Emissions, 2000-2300 (post-2100 extrapolations assume growth rate of CO_2 intensity (CO_2/GDP) over 2090–2100 is maintained through 2300)

Note: In the fifth scenario, 2000–2100 emissions are equal to the average of the emissions under the 550 ppm CO2e, full-participation, not-to-exceed scenarios considered by each of the four models.

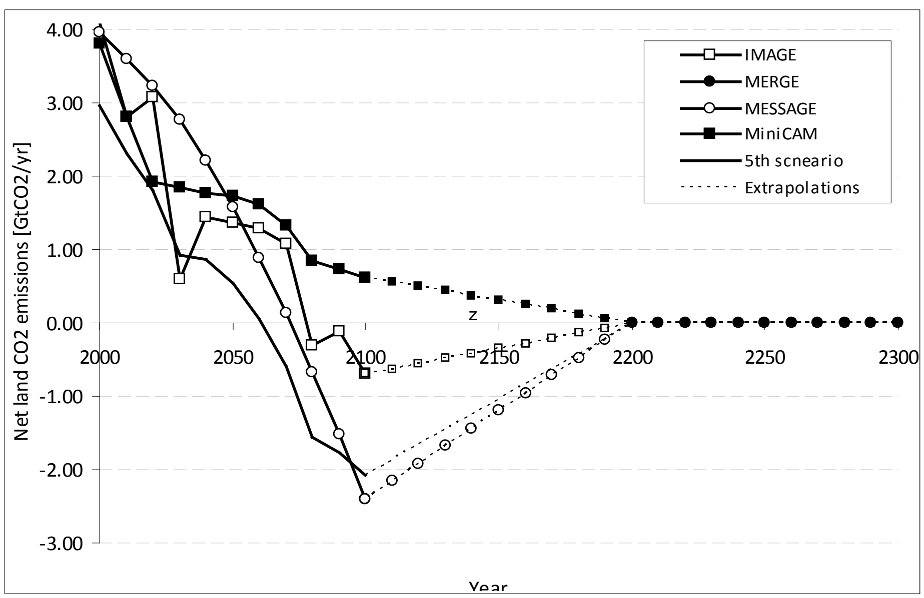

Figure 14A.9.5 Global Net Land Use CO_2 Emissions, 2000–2300 (post-2100 extrapolations assume emissions decline linearly, reaching zero in 2200)[jj]

Note: In the fifth scenario, 2000–2100 emissions are equal to the average of the emissions under the 550 ppm CO2e, full-participation, not-to-exceed scenarios considered by each of the four models.

[jj] MERGE assumes a neutral biosphere so net land CO_2 emissions are set to zero for all years for the MERGE Optimistic reference scenario, and for the MERGE component of the average 550 scenario (*i.e.*, we add up the land use emissions from the other three models and divide by 4).

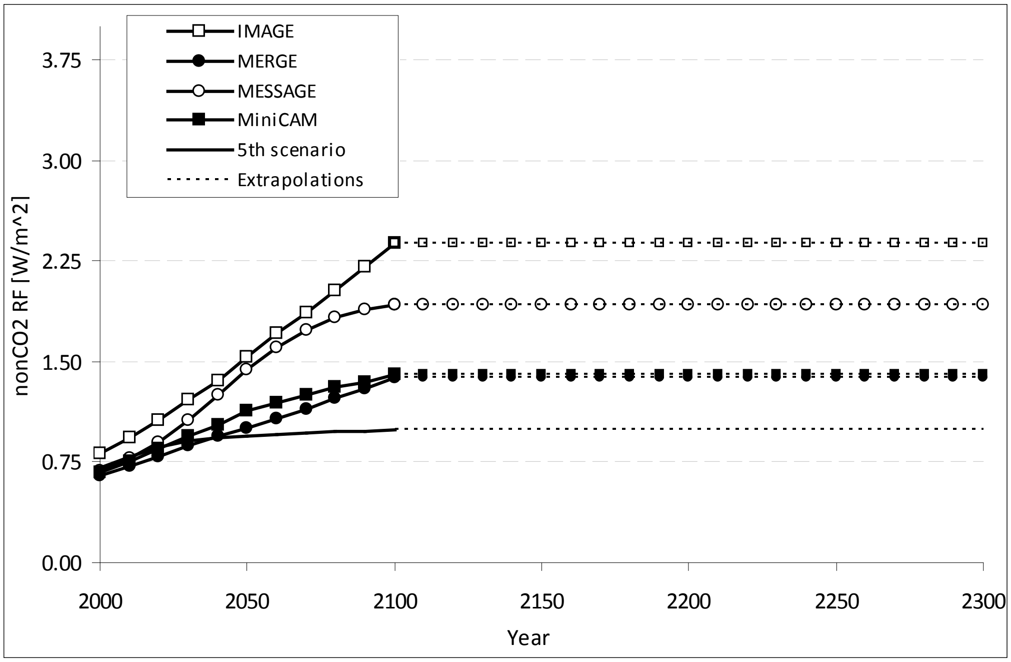

Figure 14A.9.6 Global Non-CO_2 Radiative Forcing, 2000–2300 (post-2100 extrapolations assume constant non-CO_2 radiative forcing after 2100)

Note: In the fifth scenario, 2000–2100 emissions are equal to the average of the emissions under the 550 ppm CO2e, full-participation, not-to-exceed scenarios considered by each of the four models.

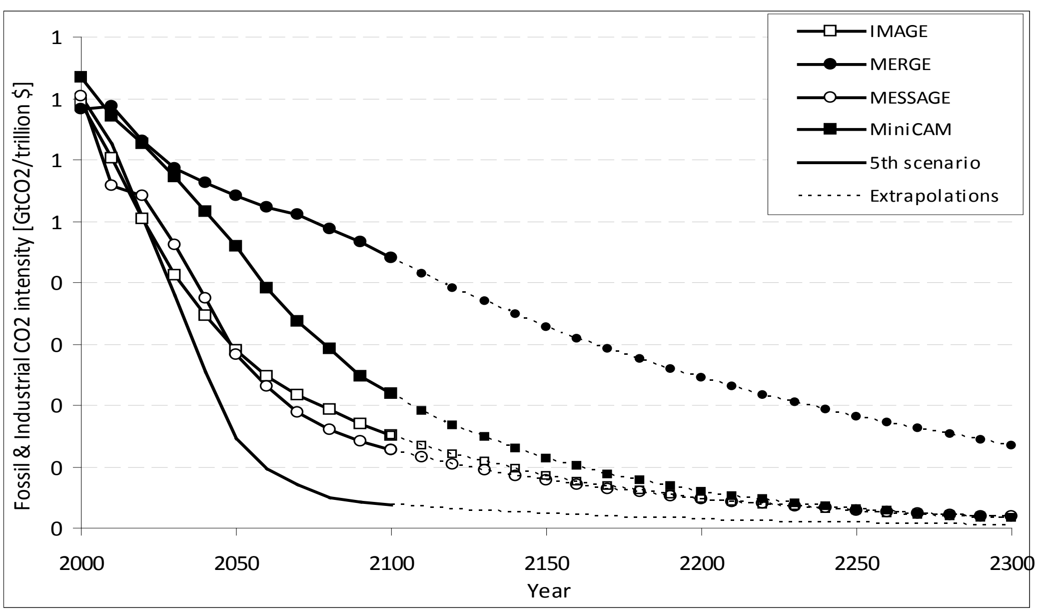

Figure 14A.9.7 Global CO_2 Intensity (fossil & industrial CO_2 emissions/GDP), 2000–2300 (post-2100 extrapolations assume decline in CO_2/GDP growth rate over 2090–2100 is maintained through 2300)

Note: In the fifth scenario, 2000–2100 emissions are equal to the average of the emissions under the 550 ppm CO_2e, full-participation, not-to-exceed scenarios considered by each of the four models.

Table 14A.9.2 2010 Global SCC Estimates at 2.5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	3.3	5.9	8.1	13.9	28.8	65.5	68.2	147.9	239.6	563.8
MERGE optimistic	1.9	3.2	4.3	7.2	14.6	34.6	36.2	79.8	124.8	288.3
Message	2.4	4.3	5.8	9.8	20.3	49.2	50.7	114.9	181.7	428.4
MiniCAM base	2.7	4.6	6.4	11.2	22.8	54.7	55.7	120.5	195.3	482.3
5th scenario	2.0	3.5	4.7	8.1	16.3	42.9	41.5	103.9	176.3	371.9
Scenario	DICE									
IMAGE	16.4	21.4	25	33.3	46.8	54.2	69.7	96.3	111.1	130.0
MERGE optimistic	9.7	12.6	14.9	19.7	27.9	31.6	40.7	54.5	63.5	73.3
Message	13.5	17.2	20.1	27	38.5	43.5	55.1	75.8	87.9	103.0
MiniCAM base	13.1	16.7	19.8	26.7	38.6	44.4	56.8	79.5	92.8	109.3
5th scenario	10.8	14	16.7	22.2	32	37.4	47.7	67.8	80.2	96.8
Scenario	FUND									
IMAGE	-33.1	-18.9	-13.3	-5.5	4.1	19.3	18.7	43.5	67.1	150.7
MERGE optimistic	-33.1	-14.8	-10	-3	5.9	14.8	20.4	43.9	65.4	132.9
Message	-32.5	-19.8	-14.6	-7.2	1.5	8.8	13.8	33.7	52.3	119.2
MiniCAM base	-31.0	-15.9	-10.7	-3.4	6	22.2	21	46.4	70.4	152.9
5th scenario	-32.2	-21.6	-16.7	-9.7	-2.3	3	6.7	20.5	34.2	96.8

Table 14A.9.3 2010 Global SCC Estimates at 3 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	2.0	3.5	4.8	8.1	16.5	39.5	41.6	90.3	142.4	327.4
MERGE optimistic	1.2	2.1	2.8	4.6	9.3	22.3	22.8	51.3	82.4	190.0
Message	1.6	2.7	3.6	6.2	12.5	30.3	31	71.4	115.6	263.0
MiniCAM base	1.7	2.8	3.8	6.5	13.2	31.8	32.4	72.6	115.4	287.0
5th scenario	1.3	2.3	3.1	5	9.6	25.4	23.6	62.1	104.7	222.5
Scenario	DICE									
IMAGE	11.0	14.5	17.2	22.8	31.6	35.8	45.4	61.9	70.8	82.1
MERGE optimistic	7.1	9.2	10.8	14.3	19.9	22	27.9	36.9	42.1	48.8
Message	9.7	12.5	14.7	19	26.6	29.8	37.8	51.1	58.6	67.4
MiniCAM base	8.8	11.5	13.6	18	25.2	28.8	36.9	50.4	57.9	67.8
5th scenario	7.9	10.1	11.8	15.6	21.6	24.9	31.8	43.7	50.8	60.6
Scenario	FUND									
IMAGE	-25.2	-15.3	-11.2	-5.6	0.9	8.2	10.4	25.4	39.7	90.3
MERGE optimistic	-24.0	-12.4	-8.7	-3.6	2.6	8	12.2	27	41.3	85.3
Message	-25.3	-16.2	-12.2	-6.8	-0.5	3.6	7.7	20.1	32.1	72.5
MiniCAM base	-23.1	-12.9	-9.3	-4	2.4	10.2	12.2	27.7	42.6	93.0
5th scenario	-24.1	-16.6	-13.2	-8.3	-3	-0.2	2.9	11.2	19.4	53.6

Table 14A.9.4 2010 Global SCC Estimates at 5 Percent Discount Rate (2007$/ton CO_2)

Percentile	1st	5th	10th	25th	50th	Avg	75th	90th	95th	99th
Scenario	PAGE									
IMAGE	0.5	0.8	1.1	1.8	3.5	8.3	8.5	19.5	31.4	67.2
MERGE optimistic	0.3	0.5	0.7	1.2	2.3	5.2	5.4	12.3	19.5	42.4
Message	0.4	0.7	0.9	1.6	3	7.2	7.2	17	28.2	60.8
MiniCAM base	0.3	0.6	0.8	1.4	2.7	6.4	6.6	15.9	24.9	52.6
5th scenario	0.3	0.6	0.8	1.3	2.3	5.5	5	12.9	22	48.7
Scenario	DICE									
IMAGE	4.2	5.4	6.2	7.6	10	10.8	13.4	16.8	18.7	21.1
MERGE optimistic	2.9	3.7	4.2	5.3	7	7.5	9.3	11.7	12.9	14.4
Message	3.9	4.9	5.5	7	9.2	9.8	12.2	15.4	17.1	18.8
MiniCAM base	3.4	4.2	4.7	6	7.9	8.6	10.7	13.5	15.1	16.9
5th scenario	3.2	4	4.6	5.7	7.6	8.2	10.2	12.8	14.3	16.0
Scenario	FUND									
IMAGE	-11.7	-8.4	-6.9	-4.6	-2.2	-1.3	0.7	4.1	7.4	17.4
MERGE optimistic	-10.6	-7.1	-5.6	-3.6	-1.3	-0.3	1.6	5.4	9.1	19.0
Message	-12.2	-8.9	-7.3	-4.9	-2.5	-1.9	0.3	3.5	6.5	15.6
MiniCAM base	-10.4	-7.2	-5.8	-3.8	-1.5	-0.6	1.3	4.8	8.2	18.0
5th scenario	-10.9	-8.3	-7	-5	-2.9	-2.7	-0.8	1.4	3.2	9.2

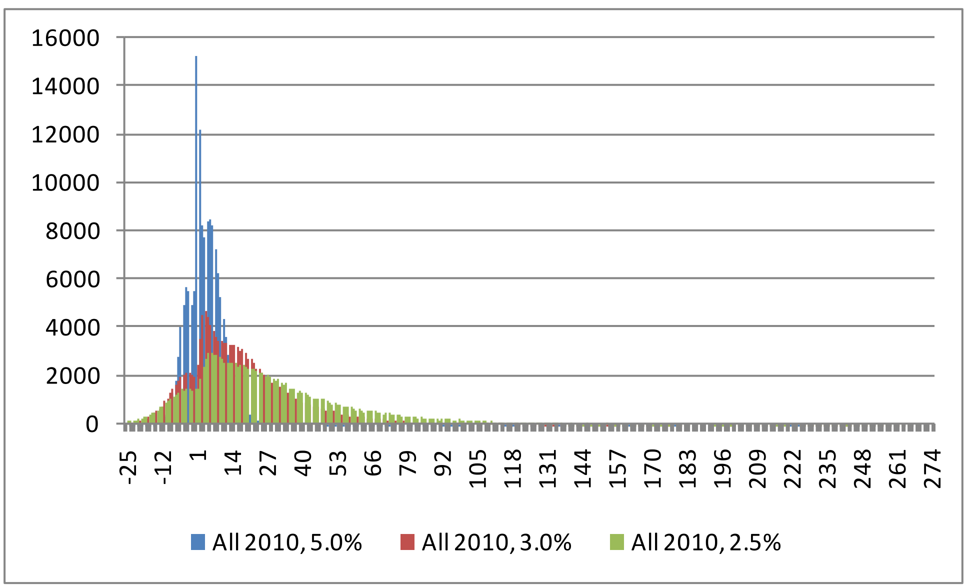

Figure 14A.9.8 Histogram of Global SCC Estimates in 2010 (2007$/ton CO_2), by Discount Rate*

* The distribution of SCC values ranges from -$5,192 to $66,116, but the X-axis has been truncated at approximately the 1st and 99th percentiles to better show the data.

Table 14A.9.5 Additional Summary Statistics of 2010 Global SCC Estimates

Discount Rate	**5%**				**3%**				**2.5%**			
Scenario	Mean	Variance	Skewness	Kurtosis	Mean	Variance	Skewness	Kurtosis	Mean	Variance	Skewness	Kurtosis
DICE	9.0	13.1	0.8	0.2	28.3	209.8	1.1	0.9	42.2	534.9	1.2	1.1
PAGE	6.5	136.0	6.3	72.4	29.8	3,383.7	8.6	151.0	49.3	9,546.0	8.7	143.8
FUND	-1.3	70.1	28.2	1,479.0	6.0	16,382.5	128.0	18,976.5	13.6	150,732.6	149.0	23,558.3

APPENDIX 14B. SOCIAL COST OF CARBON FOR REGULATORY IMPACT ANALYSIS UNDER EXECUTIVE ORDER 12866: TECHNICAL MODEL UPDATE

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Appendix 14B. Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866: technical model update

14B.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.

14B.2 Purpose

The purpose of this document is to update the schedule of social cost of carbon (SCC) [a] estimates from the 2010 interagency technical support document (TSD) (Interagency Working Group on Social Cost of Carbon 2010).[1] E.O. 13563 commits the Administration to regulatory decision making "based on the best available science."[b] Additionally, the interagency group recommended in 2010 that the SCC estimates be revisited on a regular basis or as model updates that reflect the growing body of scientific and economic knowledge become available.[c] New versions of the three integrated assessment models used by the U.S. government to estimate the SCC (DICE, FUND, and PAGE), are now available and have been published in the peer reviewed literature. While acknowledging the continued limitations of the approach taken by the interagency group in 2010 (documented in the original 2010 TSD), this document provides an update of the SCC estimates based solely on the latest peer-reviewed version of the models, replacing model versions that were developed up to ten years ago in a rapidly evolving field. It does not revisit other assumptions with regard to the discount rate, reference case socioeconomic and emission scenarios, or equilibrium climate sensitivity. Improvements in the way damages are modeled are confined to those that have been incorporated into the latest versions of the models by the developers themselves in the peer-reviewed literature. The Environmental Protection Agency (EPA), in collaboration with other Federal agencies such as the Department of Energy (DOE), continues to investigate potential improvements to the way in which economic damages associated with changes in CO_2 emissions are quantified.

Section 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]

14B.3 Summary of Model Updates

This section briefly summarizes changes integrated into the most recent versions of the three integrated assessment models (IAMs) used by the interagency group in 2010. We focus on describing those model updates that are relevant to estimating the social cost of carbon. For example, both the DICE and PAGE models now include an explicit representation of sea level rise damages. Other revisions to PAGE include: updated adaptation assumptions, revisions to ensure damages are constrained GDP, updated regional scaling of damages, and a revised treatment of potentially abrupt shifts in climate damages. In the most recent version of DICE, the model's simple carbon cycle has been updated to be more consistent with a relatively more complex climate model. The FUND model includes updated damage functions for sea level rise impacts, the agricultural sector, and reduced space heating requirements, as well as changes to the response of temperature to the buildup of GHG concentrations and the inclusion of indirect effects of methane emissions. Changes made to parts of the models that are superseded by the interagency working group's modeling assumptions – regarding climate sensitivity, discounting, and socioeconomic variables – are not discussed.

14B.3.1 DICE

Changes in the DICE model relevant for the SCC estimates developed by the interagency working group include: 1) updated parameter values for the carbon cycle model, 2) an explicit representation of sea level dynamics, and 3) a re-calibrated damage function that includes an explicit representation of economic damages from sea level rise. Changes were also made to other parts of the DICE model—including the equilibrium climate sensitivity parameter, the rate of change of total factor productivity, and the elasticity of the marginal utility of consumption—but these components of DICE are superseded by the interagency working group's assumptions and so will not be discussed here. More details on DICE2007 can be found in Nordhaus (2008)[2] and on DICE2010 in Nordhaus (2010)[3] and the associated on-line appendix containing supplemental information.

14B.3.1.1 CARBON CYCLE PARAMETERS

DICE uses a three-box model of carbon stocks and flows to represent the accumulation and transfer of carbon among the atmosphere, the shallow ocean and terrestrial biosphere, and the deep ocean. These parameters are "calibrated to match the carbon cycle in the Model for the Assessment of Greenhouse Gas Induced Climate Change (MAGICC)" (Nordhaus 2008 p 44).[2d] Carbon cycle transfer coefficient values in DICE2010 are based on re-calibration of the model to match the newer version of MAGICC (Nordhaus 2010 p 2).[3] For example, in DICE2010 in each decade, 12 percent of the carbon in the atmosphere is transferred to the shallow ocean, 4.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 94.8 percent remains in the shallow ocean, and 0.5 percent is transferred to the deep ocean. For comparison, in DICE 2007, 18.9 percent of the carbon in the atmosphere is transferred to the shallow ocean each decade, 9.7 percent of the carbon in the shallow ocean is transferred to the atmosphere, 85.3 percent remains in the shallow ocean, and 5 percent is transferred to the deep ocean.

[d] MAGICC is a simple climate model initially developed within the U.S. National Center for Atmospheric Research that has been used heavily by the Intergovernmental Panel on Climate Change (IPCC) to emulate projections from much more sophisticated state of the art earth system simulation models (Randall et al. 2007).[4]

The implication of these changes for DICE2010 is in general a weakening of the ocean as a carbon sink and therefore a higher concentration of carbon in the atmosphere than in DICE2007, for a given path of emissions. All else equal, these changes will generally increase the level of warming and therefore the SCC estimates in DICE2010 relative to those from DICE2007.

14B.3.1.2 SEA LEVEL DYNAMICS

A new feature of DICE2010 is an explicit representation of the dynamics of the global average sea level anomaly to be used in the updated damage function (discussed below). This section contains a brief description of the sea level rise (SLR) module; a more detailed description can be found on the model developer's website.[e] The average global sea level anomaly is modeled as the sum of four terms that represent contributions from: 1) thermal expansion of the oceans, 2) melting of glaciers and small ice caps, 3) melting of the Greenland ice sheet, and 4) melting of the Antarctic ice sheet.

The parameters of the four components of the SLR module are calibrated to match consensus results from the IPCC's Fourth Assessment Report.[4] [f] The rise in sea level from thermal expansion in each time period (decade) is 2 percent of the difference between the sea level in the previous period and the long run equilibrium sea level, which is 0.5 meters per degree Celsius (°C) above the average global temperature in 1900. The rise in sea level from the melting of glaciers and small ice caps occurs at a rate of 0.008 meters per decade per °C above the average global temperature in 1900.

The contribution to sea level rise from melting of the Greenland ice sheet is more complex. The equilibrium contribution to SLR is 0 meters for temperature anomalies less than 1 °C and increases linearly from 0 meters to a maximum of 7.3 meters. The contribution to SLR in each period is proportional to the difference between the previous period's sea level anomaly and the equilibrium sea level anomaly, where the constant of proportionality increases with the temperature anomaly in the current period.

The contribution to SLR from the melting of the Antarctic ice sheet is -0.001 meters per decade when the temperature anomaly is below 3 °C and increases linearly to a maximum rate of 0.025 meters per decade at a temperature anomaly of 6 °C.

14B.3.1.3 RE-CALIBRATED DAMAGE FUNCTION

Economic damages from climate change in the DICE model are represented by a fractional loss of gross economic output in each period. A portion of the remaining economic output in each period (net of climate change damages) is consumed and the remainder is invested in the physical capital stock to support future production, so each period's climate damages will reduce consumption in that period and in all future periods due to the lost investment. The fraction of output in each period that is lost due to climate change impacts is represented as one

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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]

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 ºC above 1900 levels." This compares to a loss of 3.2 percent of global output at 3.4 ºC in DICE2007. However, in DICE2010 (as downloaded from the homepage of William Nordhaus), annual damages are lower in most of the early periods but higher in later periods of the time horizon than would be calculated using the DICE2007 damage function. Specifically, the percent difference between damages in the base run of DICE2010 and those that would be calculated using the DICE2007 damage function starts at +7 percent in 2005, decreases to a low of -14 percent in 2065, then continuously increases to +20 percent by 2300 (the end of the interagency analysis time horizon), and to +160 percent by the end of the model time horizon in 2595. The large increases in the far future years of the time horizon are due to the permanence associated with damages from sea level rise, along with the assumption that the sea level is projected to continue to rise long after the global average temperature begins to decrease. The changes to the loss function generally decrease the interagency working group SCC estimates slightly, all else equal.

14B.3.2 FUND

FUND version 3.8 includes a number of changes over the previous version 3.5 used in the interagency report. Documentation supporting FUND and the model's source code for all versions of the model is available from the model authors.[g] Notable changes, due to their impact on the estimates of expected SCC, are adjustments to the space heating, agriculture, and sea level rise damage functions in addition to changes to the temperature response function and the inclusion of indirect effects from methane emissions.[h] We discuss each of these in turn.

14B.3.2.1 SPACE HEATING

In FUND, the damages associated with the change in energy needs for space heating are based on the estimated impact due to one degree of warming. These baseline damages are scaled based on the forecasted temperature anomaly's deviation from the one degree benchmark and adjusted for changes in vulnerability due to economic and energy efficiency growth. In FUND 3.5, the function that scales the base year damages adjusted for vulnerability allows for the possibility that in some simulations the benefits associated with reduced heating needs may be an

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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 CH_4 and N_2O and incorporating the indirect forcing effects of CH_4, 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.

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.

14B.3.2.2 SEA LEVEL RISE AND LAND LOSS

The FUND model explicitly includes damages associated with the inundation of dry land due to sea level rise. The amount of land lost within a region is dependent upon the proportion of the coastline being protected by adequate sea walls and the amount of sea level rise. In FUND 3.5 the function defining the potential land lost in a given year due to sea level rise is linear in the rate of sea level rise for that year. This assumption implicitly assumes that all regions are well represented by a homogeneous coastline in length and a constant uniform slope moving inland. In FUND 3.8 the function defining the potential land lost has been changed to be a non-linear function of sea level rise, thereby assuming that the slope of the shore line is not constant moving inland, with a positive first derivative. The effect of this change is to typically reduce the vulnerability of some regions to sea level rise based land loss, therefore having an effect of lowering the expected SCC estimate. The model has also been updated to assume that the value of dry land at risk of inundation is not uniform across a region but will be a decreasing function of protection measure, thereby implicitly assuming that the most valuable land will be protected first.

14B.3.2.3 AGRICULTURE

In FUND, the damages associated with the agricultural sector are measured as proportional to the sector's value. The fraction is made up of three additively separable components that represent the effects from carbon fertilization, the rate of temperature change, and the level of the temperature anomaly. In both FUND 3.5 and FUND 3.8, the fraction of the sector's value lost due to the level of the temperature anomaly is modeled as a quadratic function with an intercept of zero. In FUND 3.5, the linear and quadratic coefficients are modeled as the ratio of two normal distributions. Within this specification, as draws from the distribution in the denominator approached zero the share of the sector's value "lost" approaches (+/-) infinity independent of the temperature anomaly itself. In FUND 3.8, the linear and quadratic coefficients are drawn directly from truncated normal distributions so that they remain in the range $[0,\infty)$ and $(-\infty,0]$, respectively, where the means for the new distributions are set equal to the ratio of the means from the normal distributions used in the previous version. In general the impact of this change has been to increase the likelihood that increases in the temperature level will have either larger positive or negative effects on the agricultural sector relative to the previous version (through eliminating simulations in which the "lost" value approached (+/-) infinity). The net effect of this change on the SCC estimates is difficult to predict.

14B.3.2.4 TEMPERATURE RESPONSE MODEL

The temperature response model translates changes in global levels of radiative forcing into the current expected temperature anomaly. In FUND, a given year's increase in the cumulative temperature anomaly is based on a mean reverting function where the mean equals the equilibrium temperature anomaly that would eventually be reached if that year's level of radiative forcing were sustained. The rate of mean reversion defines the rate at which the transient temperature approaches the equilibrium. In FUND 3.5, the rate of temperature response is defined as a decreasing linear function of equilibrium climate sensitivity to capture the fact that the progressive heat uptake of the deep ocean causes the rate to slow at higher values of the equilibrium climate sensitivity. In FUND 3.8, the rate of temperature response has been updated to a quadratic function of the equilibrium climate sensitivity. This change reduces the sensitivity of the rate of temperature response to the level of the equilibrium climate sensitivity. Therefore in FUND 3.8, the temperature response will typically be faster than in the previous version. The overall effect of this change is likely to increase estimates of the SCC as higher temperatures are reached during the timeframe analyzed and as the same damages experienced in the previous version of the model are now experienced earlier and therefore discounted less.

14B.3.2.5 METHANE

The IPCC notes a series of indirect effects of methane emissions, and has developed methods for proxying such effects when computing the global warming potential of methane (Forster et al. 2007).[8] FUND 3.8 now includes the same methods for incorporating the indirect effects of methane emissions. Specifically, the average atmospheric lifetime of methane has been set to 12 years to account for the feedback of CH4 emissions on its own lifetime. The radiative forcing associated with atmospheric methane has also been increase by 40% to account for its net impact on ozone production and increase in stratospheric water vapor. The general effect of this increased radiative forcing will be to increase the estimated SCC values, where the degree to which this occurs will be dependent upon the relative curvature of the damage functions with respect to the temperature anomaly.

14B.3.3 PAGE

PAGE09 (Hope 2012)[9] includes a number of changes from PAGE2002, the version used in the 2009 SCC interagency report. The changes that most directly affect the SCC estimates include: explicitly modeling the impacts from sea level rise, revisions to the damage function to ensure damages are constrained by GDP, a change in the regional scaling of damages, a revised treatment for the probability of a discontinuity within the damage function, and revised assumptions on adaptation. The model also includes revisions to the carbon cycle feedback and the calculation of regional temperatures. More details on PAGE2009 can be found in three working papers (Hope 2011a, 2011b, 2011c).[10, 11, 12] A description of PAGE2002 can be found in Hope (2006).[13]

14B.3.3.1 SEA LEVEL RISE

While PAGE2002 aggregates all damages into two categories – economic and non-economic impacts - PAGE2009 adds a third explicit category: damages from sea level rise. In the previous version of the model, damages from sea level rise were subsumed by the other damage categories. PAGE09 models damages from sea level rise as increasing less than linearly with sea level based on the assumption that low-lying shoreline areas will be associated with higher damages than current inland areas. Damages from the economic and non-economic sector were adjusted to account for the introduction of this new category.

14B.3.3.2 REVISED DAMAGE FUNCTION TO ACCOUNT FOR SATURATION

In PAGE09, small initial economic and non-economic benefits (negative damages) are modeled for small temperature increases, but all regions eventually experience positive economic damages from climate change, where damages are the sum of additively separable polynomial functions of temperature and sea level rise. Damages transition from this polynomial function to a logistic path once they exceed a certain proportion of remaining Gross Domestic Product (GDP) to ensure that damages do not exceed 100 percent of GDP. This differs from PAGE2002, which allowed Eastern Europe to potentially experience large benefits from temperature increases, and which also did not bound the possible damages that could be experienced.

14B.3.3.3 REGIONAL SCALING FACTORS

As in the previous version of PAGE, the PAGE09 model calculates the damages for the European Union (EU) and then, assumes that damages for other regions are proportional based on a given scaling factor. The scaling factor in PAGE09 is based on the length of a region's coastline relative to the EU (Hope 2011b).[11] Because of the long coastline in the EU, other regions are, on average, less vulnerable than the EU for the same sea level and temperature increase, but all regions have a positive scaling factor. PAGE2002 based its scaling factors on four studies reported in the IPCC's third assessment report, and allowed for benefits from temperature increase in Eastern Europe, smaller impacts in developing countries, and higher damages in developing countries.

14B.3.3.4 PROBABILITY OF A DISCONTINUITY

In PAGE2002, the damages associated with a "discontinuity" were modeled as an expected value. That is, additional damages from an extreme event, such as extreme melting of the Greenland ice sheet, were multiplied by the probability of the event occurring and added to the damage estimate. In PAGE09, the probability of "discontinuity" is treated as a discrete event for each year in the model. The damages for each model run are estimated 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.

14B.3.3.5 ADAPTATION

As in PAGE2002, adaptation is available to increase the tolerable level of temperature change and can help mitigate any climate change impacts that still occur. In PAGE this adaptation is the same regardless of the temperature change or sea level rise and is therefore akin to what is more commonly considered a reduction in vulnerability. It is modeled by modifying the temperature change and sea level rise used in the damage function or by reducing the damages by some percentage. PAGE09 assumes a smaller decrease in vulnerability than the previous version of the model and assumes that it will take longer for this change in vulnerability to be realized. In the aggregated economic sector, at the time of full implementation, this adaptation will mitigate all damages up to a temperature increase of 1°C, and for temperature anomalies between 1°C and 3°C, it will reduce damages by 15-30 percent (depending on the region). However, it takes 20 years to fully implement this adaptation. In PAGE2002, adaptation was assumed to reduce economic sector damages up to 3°C by 50-90 percent after 20 years. Beyond 3°C, no adaptation is assumed to be available to mitigate the impacts of climate change. For the non-economic sector, in PAGE09 adaptation is available to reduce 15 percent of the damages due to a temperature increase between 0°C and 2°C and is assumed to take 40 years to fully implement, instead of 25 percent of the damages over 20 years assumed in PAGE2002. Similarly, adaptation is assumed to alleviate 25-50 percent of the damages from the first 0.20 to 0.25 meters of sea level rise but is assumed to be ineffective thereafter. Hope (2011c)[12] estimates that the less optimistic assumptions regarding the ability to offset impacts of temperature and sea level rise via adaptation increase the SCC by approximately 30 percent.

14B.3.3.6 OTHER NOTEWORTHY CHANGES

Two other changes in the model are worth noting. A revised carbon cycle feedback is introduced to simulate decreased CO_2 absorption by the terrestrial biosphere and ocean as the temperature rises. This feedback is linear in the average global and annual temperature anomaly but is capped at a maximum value. In the previous version of PAGE, an additional amount was added to the CO_2 emissions each period to account for a decrease in ocean absorption and a loss of soil carbon. Also updated is the method by which the average global and annual temperature anomaly is downscaled to determine annual average regional temperature anomalies to be used in the regional damage functions. In the previous version of PAGE, the scaling was determined solely based on regional difference in emissions of sulfate aerosols. In PAGE09, this regional temperature anomaly is further adjusted using an additive factor that is based on the average absolute latitude of a region relative to the area weighted average absolute latitude of the Earth's landmass.

14B.4 Revised SCC Estimates

The updated versions of the three integrated assessment models were run using the same methodology detailed in the 2010 TSD.[1] The approach along with the inputs for the socioeconomic emissions scenarios, equilibrium climate sensitivity distribution, and discount rate remains the same. This includes the five reference scenarios based on the EMF-22 modeling exercise, the Roe and Baker equilibrium climate sensitivity distribution calibrated to the Fourth Assessment Report of the IPCC, and three constant discount rates of 2.5, 3, and 5 percent.

As was previously the case, the use of three models, three discount rates, and five scenarios produces 45 separate distributions for the SCC. The approach laid out in the TSD applied equal weight to each model and socioeconomic scenario in order to reduce the dimensionality down to three separate distributions representative of the three discount rates. The interagency group selected four values from these distributions for use in regulatory analysis. Three values are based on the average SCC across models and socio-economic-emissions scenarios at the 2.5, 3, and 5 percent discount rates, respectively. The fourth value was chosen to represent the higher-than-expected economic impacts from climate change further out in the tails of the SCC distribution. For this purpose, the 95th percentile of the SCC estimates at a 3 percent discount rate was chosen. (A detailed set of percentiles by model and scenario combination is available in the Annex.) As noted in the original TSD, "the 3 percent discount rate is the central value, and so the central value that emerges is the average SCC across models at the 3 percent discount rate" (TSD, p. 25). However, for purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance and value of including all four SCC values.

Table 14B.4.1 shows the four selected SCC estimates in five year increments from 2010 to 2050. Values for 2010, 2020, 2030, 2040, and 2050 are calculated by first combining all outputs (10,000 estimates per model run) from all scenarios and models for a given discount rate. Values for the years in between are calculated using basic linear interpolation. The full set of annual SCC estimates between 2010 and 2050 is reported in the Annex.

Table 14B.4.1 Revised Social Cost of CO_2, 2010 – 2050 (in 2007 dollars per ton of CO_2)

Discount Year	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 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 14B.4.1 illustrates where the four SCC values for 2020 fall within the full distribution for each discount rate based on the combined set of runs for each model and scenario (150,000 estimates in total for each discount rate). In general, the distributions are skewed to the right and have long tails. The Figure also shows that the lower the discount rate, the longer the right tail of the distribution.

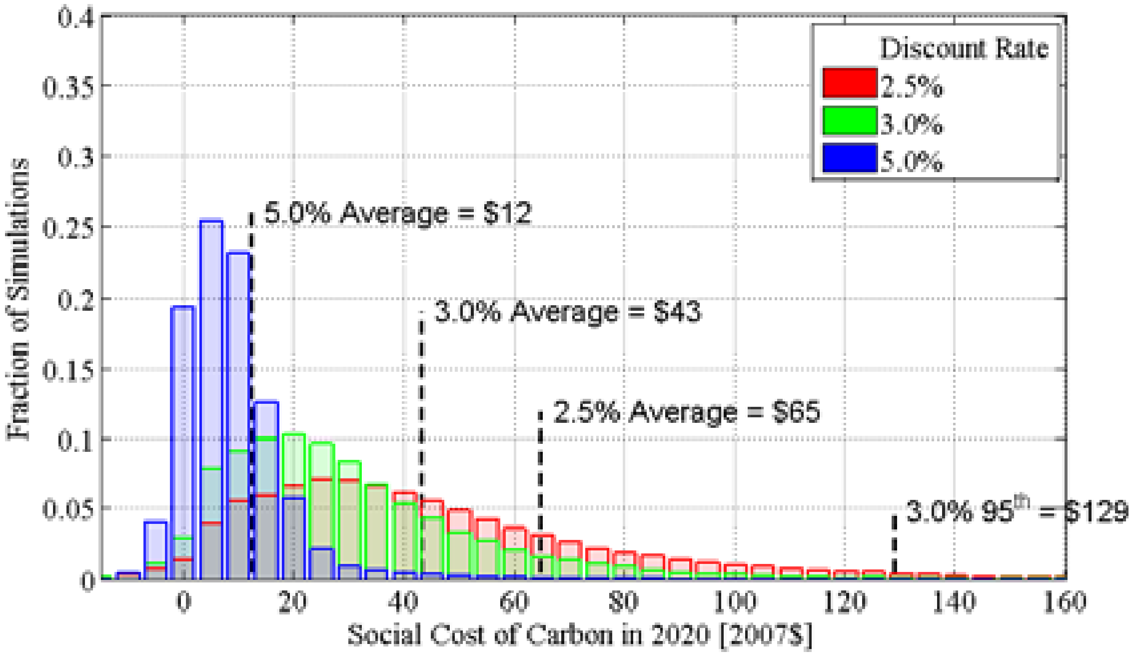

Figure 14B.4.1 Distribution of SCC Estimates for 2020 (in 2007$ per ton CO_2)

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 14B.4.2 illustrates how the growth rate for these four SCC estimates varies over time.

Table 14B.4.2 Average Annual Growth Rates of SCC Estimates between 2010 and 2050

Average Annual Rate (%)	5.0% Avg	3.0% Avg	2.5% Avg	3.0% 95th
2010-2020	1.2%	3.2%	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.

14B.5 Other Model Limitations or Research Gaps

The 2010 interagency SCC technical support report discusses a number of important limitations for which additional research is needed. In particular, the document highlights the need to improve the quantification of both non-catastrophic and catastrophic damages, the treatment of adaptation and technological change, and the way in which inter-regional and inter-sectoral linkages are modeled. It also discusses the need to more carefully assess the implications of risk aversion for SCC estimation as well as the inability to perfectly substitute between climate and non-climate goods at higher temperature increases, both of which have implications for the discount rate used. EPA, DOE, and other agencies continue to engage in long-term research work on modeling and valuation of climate impacts that we expect will inform improvements in SCC estimation in the future.

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ANNEX

Table 14B.5.1 Annual SCC Values: 2010-2050 (2007$/ton CO_2)

Discount 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 14B.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 14B.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 14B.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

CHAPTER 15. UTILITY IMPACT ANALYSIS

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CHAPTER 15. UTILITY IMPACT ANALYSIS

15.1 INTRODUCTION

In the utility impact analysis, 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's (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 commercial refrigeration equipment, DOE used the version of NEMS based on *AEO2013*.[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.

15.2 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 (terawatt-hours (TWh)) from the stock of electric

[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003), March, 2003.
[b] DOE/EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on DOE/EIA assumptions, DOE refers to it by the name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed).

generating capacity changes, the total generation capacity itself (gigawatts (GW)) may change, and the mix of capacity by fuel type may change. Each of these effects can vary for different types of end use. The change in total generating capacity is sensitive to the degree to which the end-use is peak coincident, while the capacity mix is sensitive to the hourly load shape associated with the end use.

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 quadrillion British thermal units (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 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 percent) of the generation capacity base.

15.3 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.

15.3.1 Installed Capacity

The figures in this section show the changes in U.S. electricity installed capacity that result for each TSL by major plant type for selected years. Note that a negative number means an increase in capacity under a TSL.

[c] These reductions are defined relative to the *AEO* Reference Case.

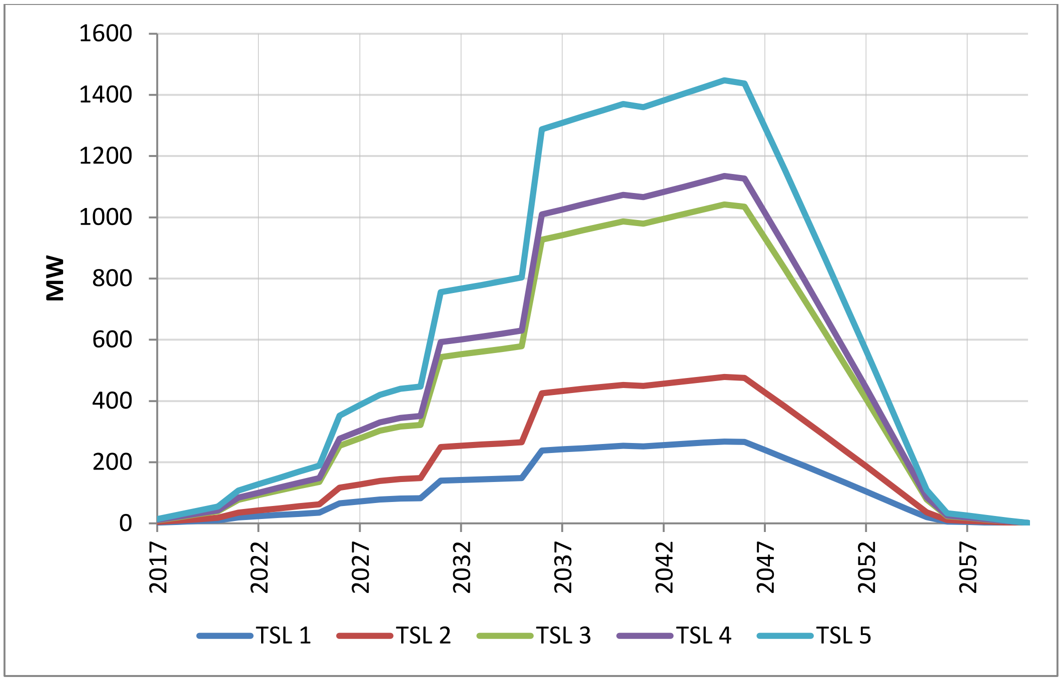

Figure 15.3.1 Commercial Refrigeration Equipment: Total Capacity Reduction

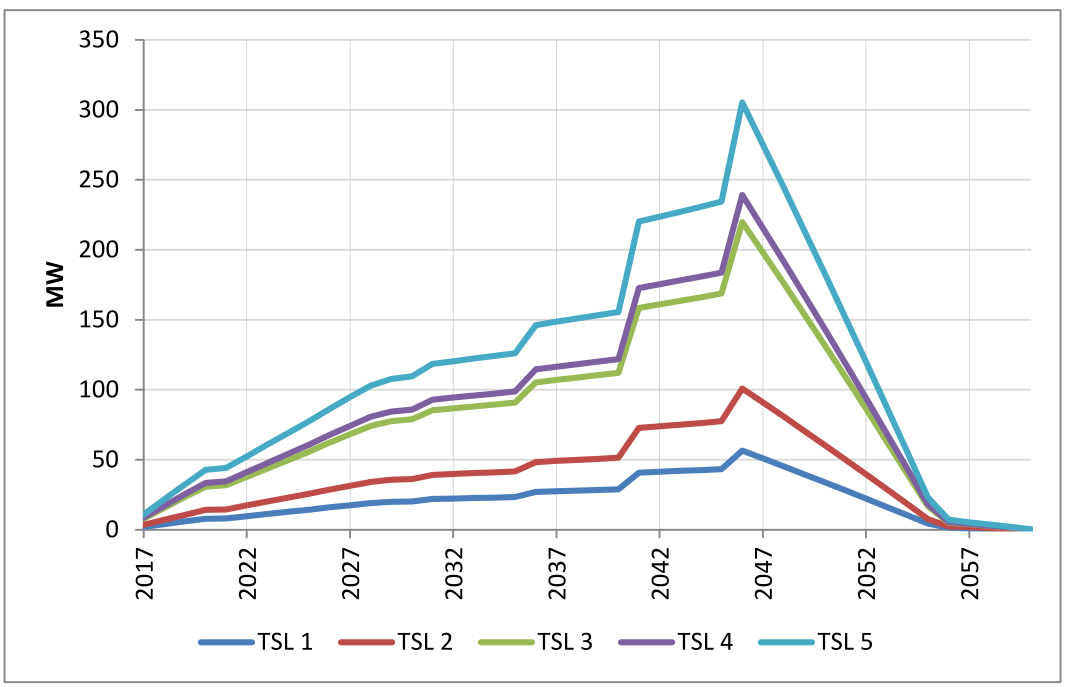

Figure 15.3.2 Commercial Refrigeration Equipment: Coal Capacity Reduction

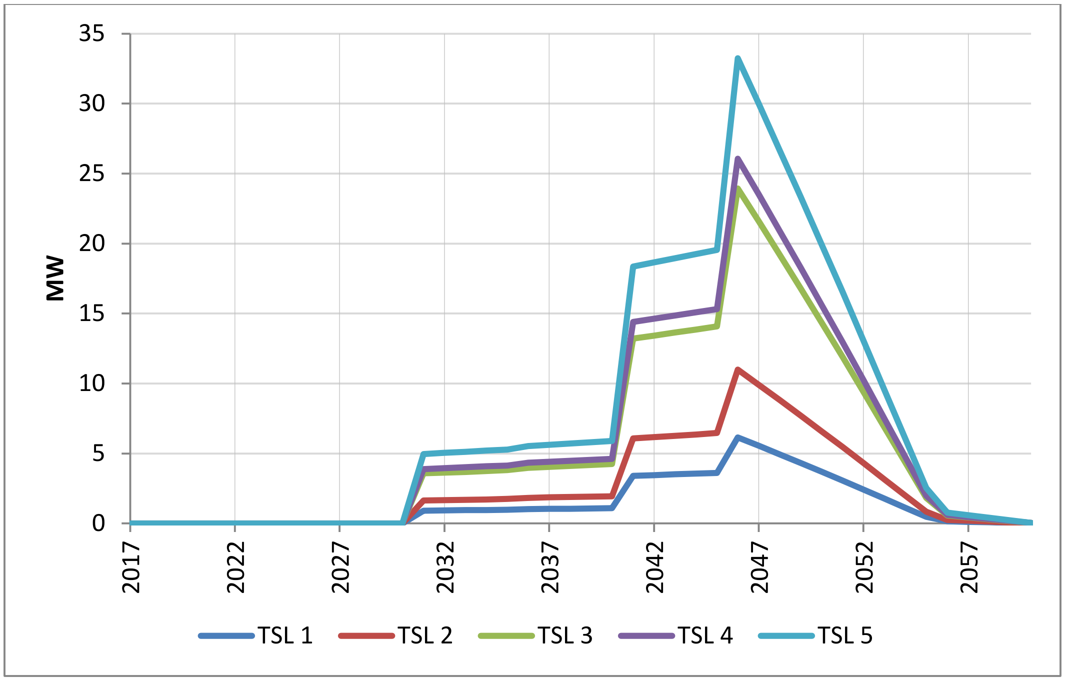

Figure 15.3.3 Commercial Refrigeration Equipment: Nuclear Capacity Reduction

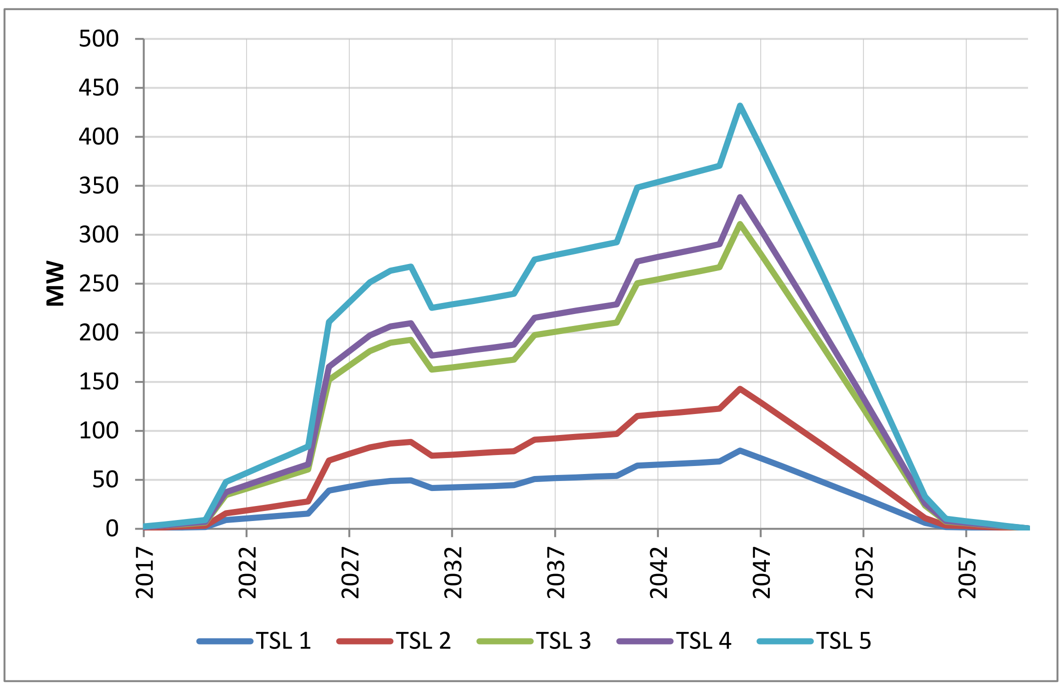

Figure 15.3.4 Commercial Refrigeration Equipment: Gas Combined Cycle Capacity Reduction

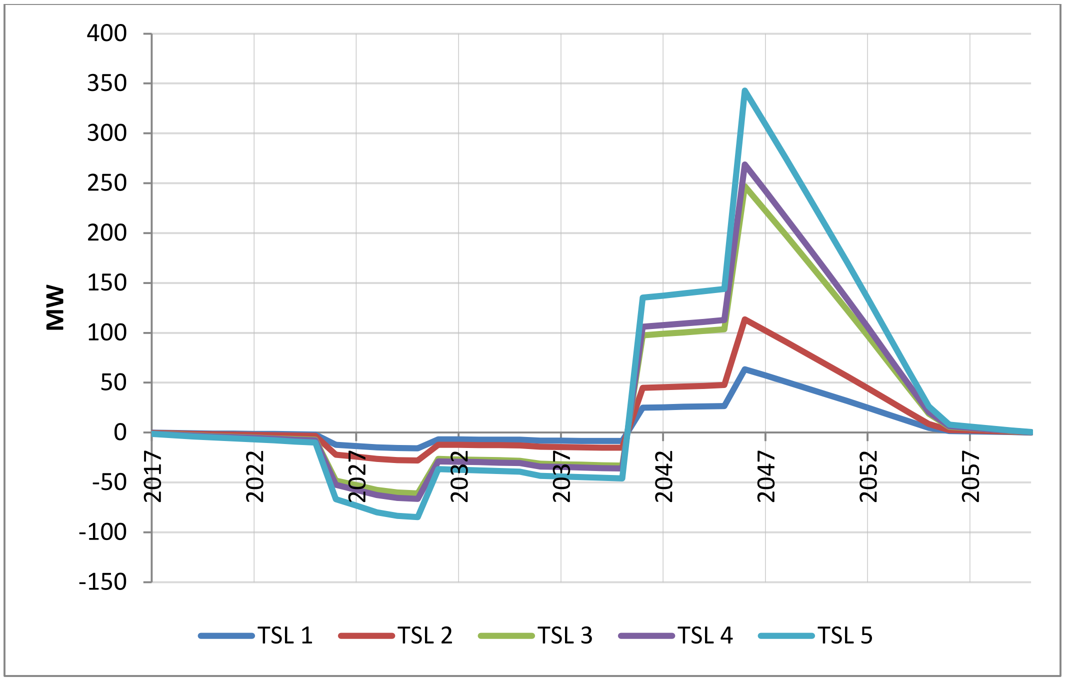

Figure 15.3.5 Commercial Refrigeration Equipment: Peaking Capacity Reduction

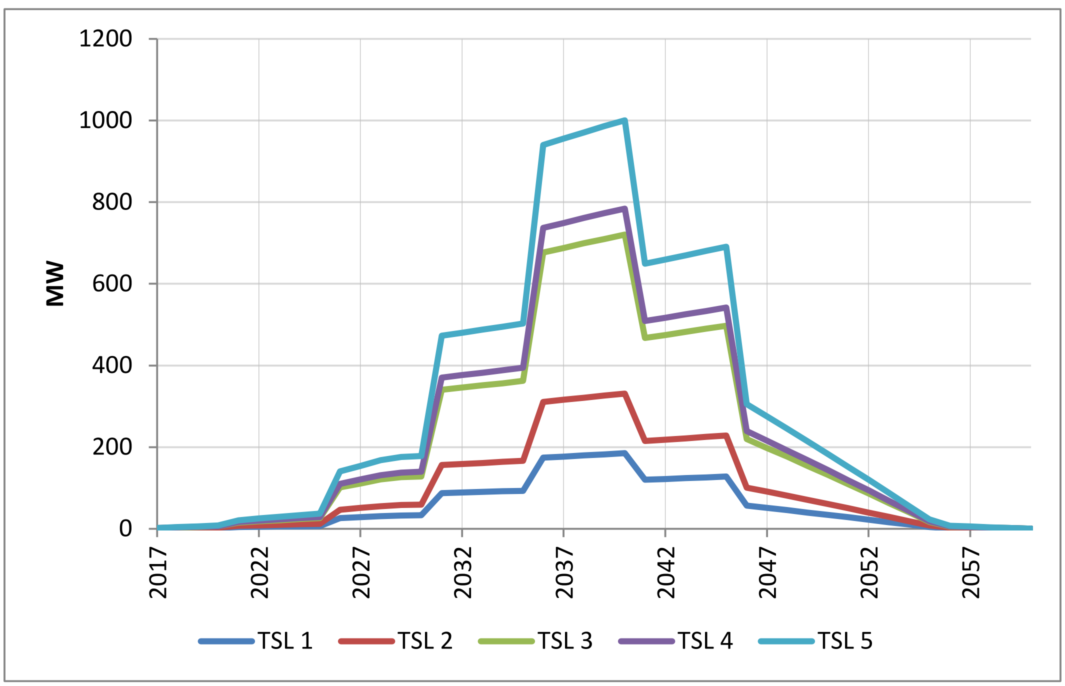

Figure 15.3.6 Commercial Refrigeration Equipment: Renewables Capacity Reduction

15.3.2 Electricity Generation

The figures in this section show the annual change in electricity generation that result for each TSL by 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.

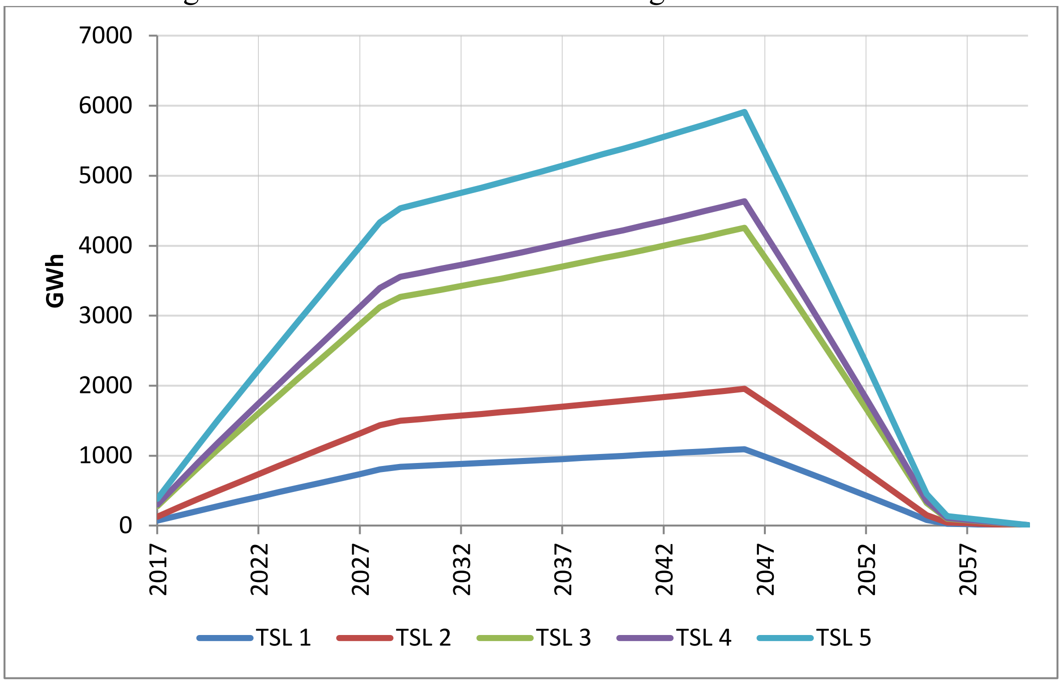

Figure 15.3.7 Commercial Refrigeration Equipment: Total Generation Reduction

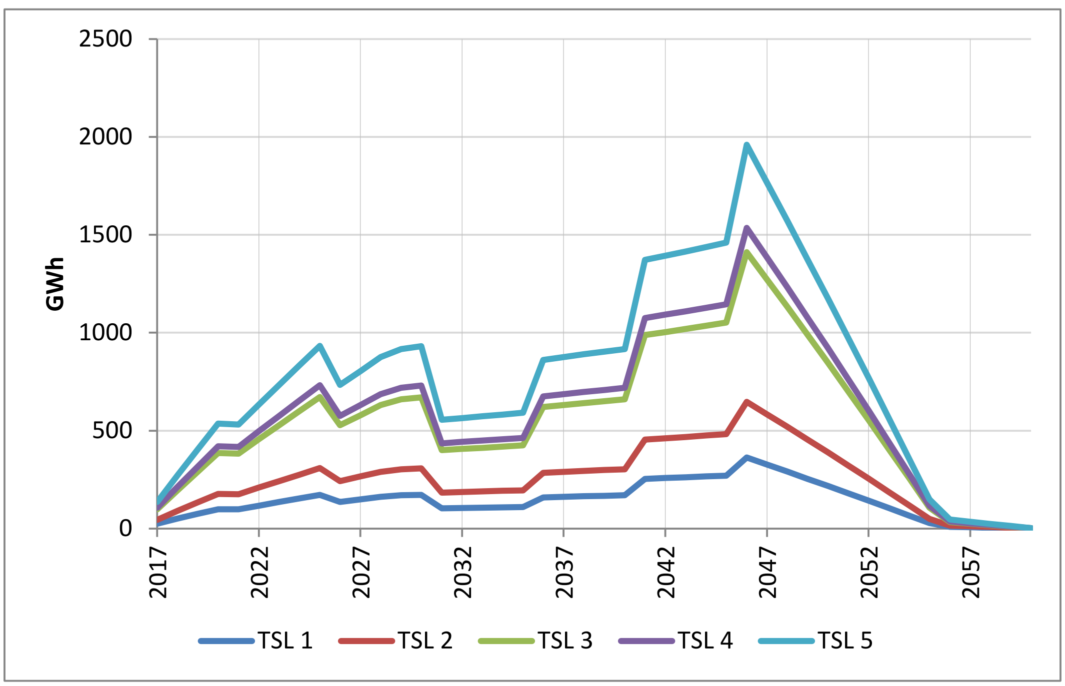

Figure 15.3.8 Commercial Refrigeration Equipment: Coal Generation Reduction

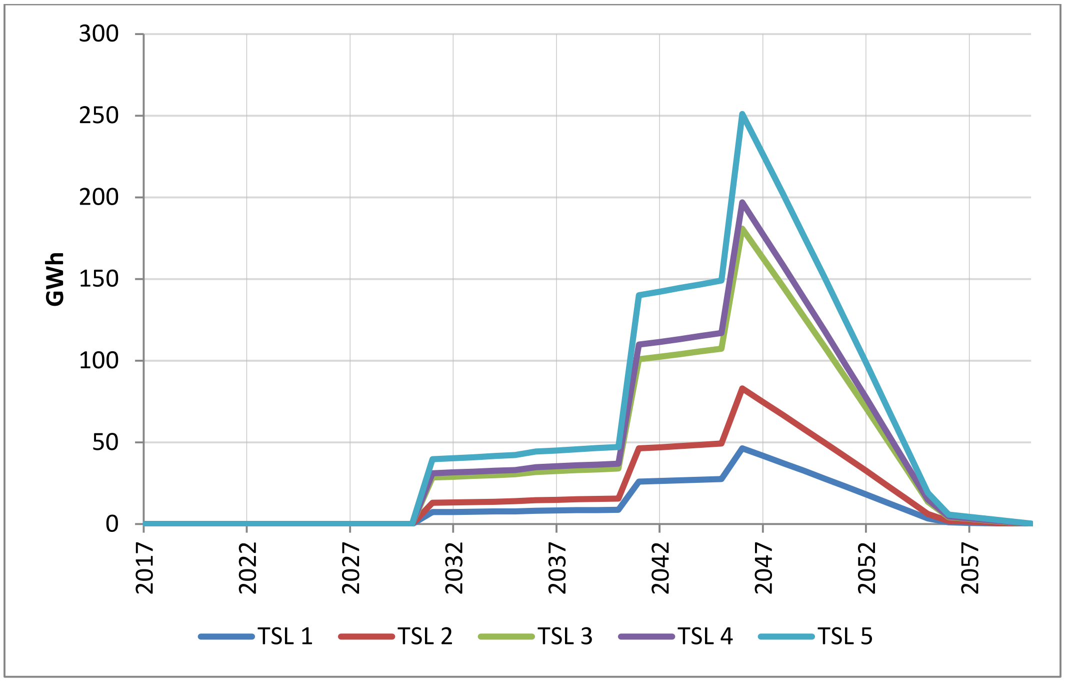

Figure 15.3.9 Commercial Refrigeration Equipment: Nuclear Generation Reduction

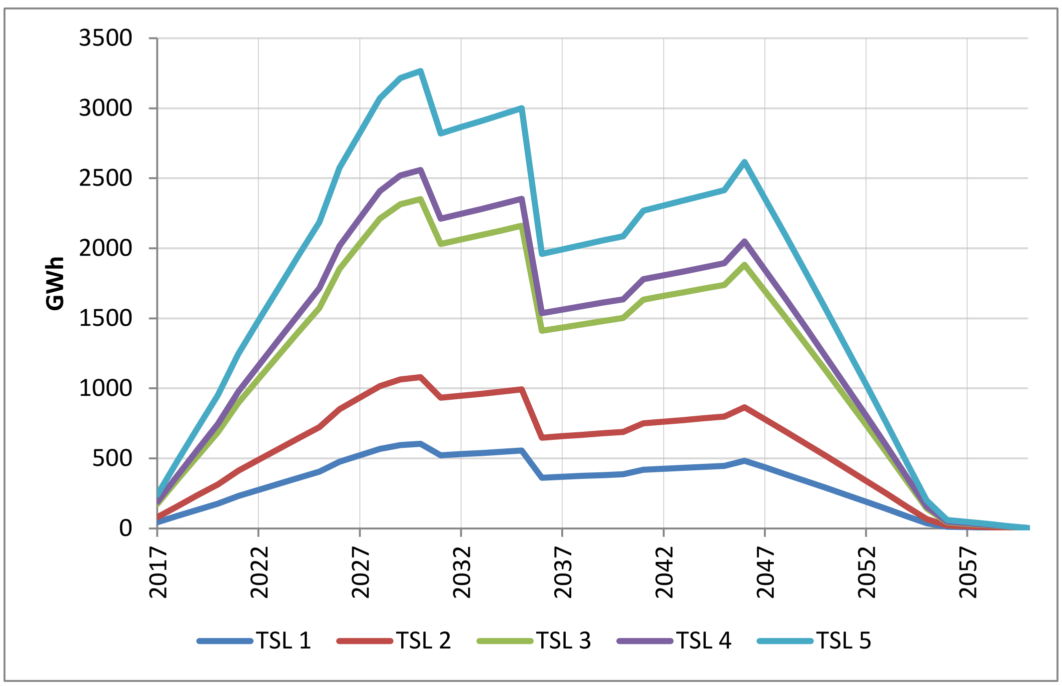

Figure 15.3.10 Commercial Refrigeration Equipment: Gas Combined Cycle Generation Reduction

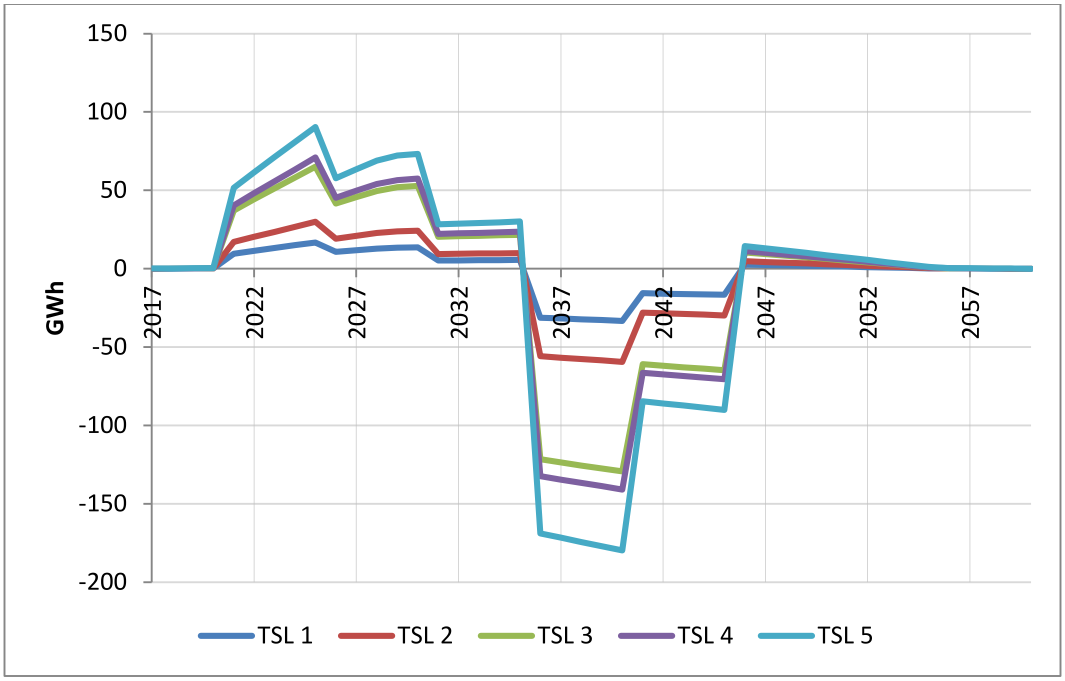

Figure 15.3.11 Commercial Refrigeration Equipment: Peaking Generation Reduction

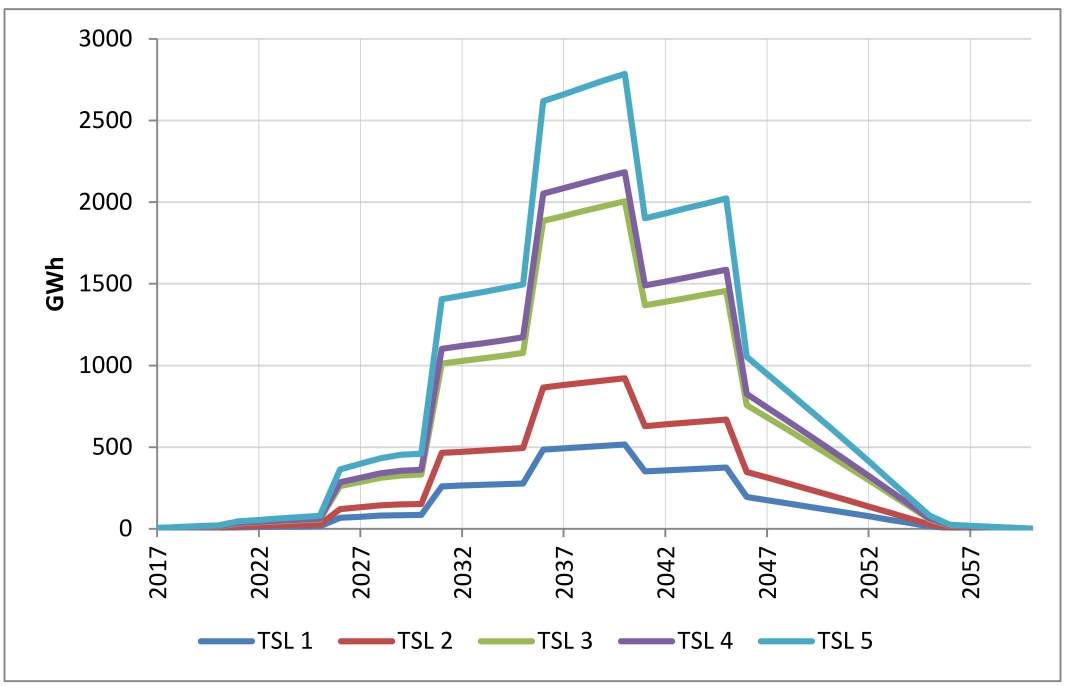

Figure 15.3.12 Commercial Refrigeration Equipment: Renewables Generation Reduction

15.3.3 Results Summary

Table 15.3.1 presents a summary of the utility impact results for commercial refrigeration equipment.

Table 15.3.1 CRE: Summary of Utility Impact Results

Year	TSL				
	1	2	3	4	5
Installed Capacity Reduction (MW)					
2020	10.13	18.10	39.42	42.92	54.75
2025	34.99	62.51	136.15	148.23	189.09
2030	82.72	147.80	321.91	350.47	447.10
2035	148.65	265.58	578.45	629.77	803.39
2040	253.41	452.75	986.11	1,073.61	1,369.59
Electricity Generation Reduction (GWh)					
2020	279.06	498.57	1,085.92	1,182.27	1,508.21
2025	607.33	1,085.07	2,363.35	2,573.04	3,282.41
2030	852.78	1,523.61	3,318.51	3,612.96	4,609.02
2035	921.64	1,646.63	3,586.45	3,904.67	4,981.15
2040	996.24	1,779.91	3,876.76	4,220.74	5,384.36

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CHAPTER 16. EMPLOYMENT IMPACT ANALYSIS

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16.1 INTRODUCTION

The U.S. Department of Energy's (DOE) employment impact analysis is designed to estimate indirect national job creation or elimination resulting from proposed standards due to reallocation of associated expenditures for purchasing and operating commercial refrigeration equipment. Job increases or decreases reported in this chapter are separate from the direct commercial refrigeration equipment sector employment impacts reported in chapter 12, and reflect the employment impact of efficiency standards on all other sectors of the economy. DOE conducted this analysis as part of this notice of proposed rulemaking (NOPR).

16.2 ASSUMPTIONS

DOE expects amended energy conservation standards to decrease energy use and therefore reduce energy expenditures. The savings in energy expenditures may be spent on new investments, or not spent at all (*i.e.*, they may remain "saved"). Amended standards may increase the purchase price of commercial refrigeration equipment, including the retail price plus sales tax, and could in some cases increase installation costs.

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. DOE evaluated direct employment impacts at manufacturers' facilities in the manufacturer impact analysis (see chapter 12).

DOE notes that the ImSET model (Impact of Sector Energy Technologies) 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 overestimate the magnitude of actual job impacts over the long run for this rule. Since input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. DOE therefore included a qualitative discussion of how labor markets are likely to respond in the longer term. In future rulemakings, DOE may consider the use of other modeling approaches for examining long-run employment impacts.

16.3 METHODOLOGY

DOE 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 (PNNL) developed the model using ImSET 3.1.1[2] as a successor to Impact of Building Energy Efficiency Programs (ImBuild),[3] a special purpose version of the Impact Analysis for Planning (IMPLAN)[4] national input/output model. ImSET estimates the employment and income effects of building energy technologies. Compared with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy-efficiency investments in buildings.

In an input/output model, the level of employment in an economy is determined by the relationships of different sectors of the economy and 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 equipment 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 customers 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 commercial refrigeration equipment manufacturing sector estimated in chapter 12 using the Government Regulatory Impact Model (GRIM). The methodologies used and the sectors analyzed in the ImSET and GRIM models are different.

16.4 SHORT-TERM RESULTS

The results in this section refer to impacts of commercial refrigeration 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 commercial refrigeration equipment. DOE presents the summary impact.

Conceptually, one can consider the impact of the rule in its first year on three aggregate sectors: the commercial refrigeration 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 commercial refrigeration 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 commercial refrigeration 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 16.4.1 presents the modeled net employment impact from the rule in 2017 and 2021. As mentioned in chapter 12, 90 percent of commercial refrigeration equipment is produced domestically and 10 percent is imported. The net employment impact estimate is sensitive to assumptions regarding the return to the U.S. economy of money spent on imported commercial refrigeration equipment. The two scenarios bounding the ranges presented in Table 16.4.1 represent situations in which none of the money spent on imported microwaves returns to the U.S. economy and all of the money spent on imported commercial refrigeration returns to the U.S. economy (low and high bounds, respectively). The U.S. trade deficit in recent years suggests that between 50 percent and 75 percent of the money spent on imported commercial refrigeration equipment is likely to return, with employment impacts falling within the ranges presented below.

Table 16.4.1 Net Short-Term Change in Employment

Trial Standard Level	2017*	2021
1	35 to 38	198 to 201
2	53 to 61	345 to 354
3	74 to 108	719 to 749
4	60 to 105	760 to 801
5	(728) to (363)**	130 to 504

* Compliance date of standard levels is 2017.
** Values in parentheses are negative values.

16.5 LONG-TERM RESULTS

Due to the short payback period of energy-efficiency improvements mandated by this rule, over the long term DOE expects the energy savings to customers to increasingly dominate the increase in equipment costs, resulting in increased aggregate savings to customers. As a result, DOE expects demand for electricity to decrease 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 and toward consumer goods. Note that in long-run equilibrium there is no net effect on total employment because wages adjust to bring the labor market into equilibrium. For context, the Office of Management and Budget (OMB) currently assumes that the official unemployment rate may decline to 6.9 percent in 2014 and drop further to 5.3 percent in 2017.[5] The unemployment rate in 2017 is generally considered to be close to "full employment." When an economy is at full employment, any effects on net employment are likely to be transitory as workers change jobs (*e.g.*, some workers may need to be retrained or require time to search for new jobs) rather than enter or exit longer-term unemployment. Nonetheless, even to the extent that markets are slow to adjust, DOE anticipates that net labor market impacts will be negligible over time due to the small magnitude of the short-term effects presented in Table 16.4.1. The ImSET model projections, assuming no price or wage effects until 2021, are included in Table 16.4.1.

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CHAPTER 17. REGULATORY IMPACT ANALYSIS

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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 (Sept. 30, 1993).

DOE has identified five major alternatives to standards that represent feasible policy options to reduce commercial refrigeration equipment energy consumption. DOE evaluated each alternative's ability to achieve significant energy savings at a reasonable cost, and compared 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 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 uses the national impact analysis (NIA) spreadsheet models to calculate the national energy savings (NES) and the net present value (NPV) corresponding to each non-regulatory alternative. 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 commercial refrigeration equipment. After quantifying each alternative, DOE makes the appropriate revisions to the inputs in the NIA models to estimate energy savings compared to the base-case scenario. Key inputs that DOE typically revises in these models include the following:

- 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
- product stock data

The key measures of the impact of each alternative are the following:

- Energy use reflects the cumulative energy use of the product from the effective date of the new standard to the year 2046.
- National energy savings represents the 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 analysis period (2046).

17.3 NON-REGULATORY POLICIES

17.3.1 No New Regulatory Action

The base-case scenario is the one in which no new regulatory action is taken with regard to the energy efficiency of commercial refrigeration equipment, as described in the NIA (chapter 10 of this TSD). The base-case scenario provides the basis of comparison for all other non-regulatory alternatives. By definition, no new regulatory action yields zero energy savings and an NPV of zero dollars.

17.3.2 Customer Rebates

Customer rebates cover a portion of the difference in incremental product price between products meeting baseline efficiency levels and those meeting higher efficiency levels, resulting in a higher percentage of consumers purchasing more efficacious models and decreased aggregated energy use compared to the base-case scenario.

DOE surveyed the various rebate programs available in the United States in 2011. Typically, local utility companies offer rebates to grocery stores that retrofit their display cases with energy efficiency components, such as light-emitting diode (LED) lamps, electronically commutated motor (ECM) fan motors, night curtains, and higher efficiency doors. As an example, Eugene Water and Electric Board offers $16 per linear foot of LED when a refrigeration case is retrofit to replace T8 fluorescent lamps; $11 per linear foot for installing night covers on a vertical open refrigerator; $3 per lamp for installing a motion sensor control; and $35 per motor when a refrigerated display case is retrofitted with ECM fan motors.[1] Examples of similar rebate programs on offer are from Pacific Gas and Electric Company as part of its EnergySmart Grocer Program[2] and Santee Cooper Business as part of its 2010−2011 Commercial Prescriptive Rebate Program.[3]

DOE used the rebate amounts on offer and compared them to the manufacturer selling price (MSP) increments of the higher design option levels (chapter 5 of this TSD) of certain equipment classes. Certain rebates on offer, such as rebates for retrofitting with ECM fan motors, were not applicable to this rulemaking because the commercial refrigeration equipment that is compliant to the 2009 final rule standards will most likely incorporate ECM fan motors. Therefore, the ECM fan motors are likely to be part of the base-case scenario for the current rulemaking. DOE calculated the rebate amounts a percentage of the MSP increments. An approximate calculation of the rebate amount with respect to trial standard level (TSL) 4 for VOP.RC.M and VCT.RC.L equipment classes yielded a rebate percentage range from 50 to 80 percent.

Other types of rebates, on offer from a large number of utilities across the nation, are in the form of fixed rebate amounts for commercial customers who purchase refrigerators and freezers that are ENERGY STAR® compliant. DOE compared the typical rebate amounts to the MSP increments associated with TSL 4 for VCS.SC.M and VCT.SC.L equipment classes and found that the rebate amount as a percentage of MSP increments was approximately 50 percent in most cases.

Based on comparison with the incremental MSP values obtained from the engineering analysis, DOE chose to model a scenario where customers are offered, as rebates, 60 percent of the incremental installed cost of the commercial refrigeration equipment. The value of 60 percent is very high compared to most rebate programs and was chosen to approximate a high-rebate scenario.

DOE applied the 60-percent rebate to MSP increments at all efficiency levels for all the equipment classes and calculated the new installed costs of the equipment. These new installed costs were then used to recalculate the market shares of efficiency levels (see chapter 10 of this TSD). As the new equipment installed price of higher efficiency equipment is reduced, the market shares of efficiency levels shift towards higher efficiency levels resulting in savings compared to the base-case scenario.

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 customer to taxpayers as a whole. Consequently, DOE assumed that equipment costs in the rebates scenario were identical to the NIA base-case scenario.

DOE assumed that rebates would remain in effect for the duration of the analysis period. Table 17.3.1 presents the NES and NPV values for the 60-percent rebate scenario and compares them against the NES and NPV values at TSL 4 obtained from NIA (see TSD chapter 10).

Table 17.3.1 Customer Rebate NES and NPV Comparison to TSL 4

Policy Alternatives	**Cumulative Energy Savings*** *quads*	**Net Present Value**** *billion 2012$*	
		7% Discount Rate	**3% Discount Rate**
No New Regulatory Action	0	0	0
Customer Rebates (60% of MSP increments)	0.198	0.055	0.122
TSL 4	0.985	1.606	4.067

* Energy savings are in primary energy 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).

For the tax credits scenario, DOE did not find a suitable program for commercial customers to model the scenario. Therefore, DOE used a 5-percent/10-percent tax credit scenario. DOE first calculated the MSP increments over baseline for each TSL for each equipment class. For TSLs that had an increase in MSP between 10 and 15 percent over the baseline MSP, DOE applied a 5-percent tax credit, where the amount of tax credit is equal to 5-percent of the MSP of the higher efficiency equipment. For TSLs that had increase of 15 percent or more in MSP values over the baseline MSP, DOE applied a 10-percent tax credit. This type of tax credit scenario is an attempt to approximate a model where the tax credits are proportional to the magnitude of efficiency improvement with the implicit assumption being that the amount of MSP increase is proportional to the magnitude of increase in energy efficiency.

DOE applied the 5-percent/10-percent tax credit to MSP increments at all efficiency levels, as described above, for all the equipment classes and calculated the new installed costs of the equipment. These new installed costs were then used to recalculate the market shares of efficiency levels. As the new equipment installed price of higher efficiency equipment is reduced, the market shares of efficiency levels shift towards higher efficiency levels, resulting in savings compared to the base-case scenario.

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 17.3.2 presents the NES and NPV values for the 5-percent/10-percent tax credit scenario and compares them against the NES and NPV values at TSL 4 obtained from NIA (see TSD chapter 10).

Table 17.3.2 Tax Credit NES and NPV Comparison to TSL 4

Policy Alternatives	Cumulative Energy Savings* *quads*	Net Present Value** *billion 2012$*	
		7% Discount Rate	3% Discount Rate
No New Regulatory Action	0	0	0
Customer Tax Credits	0.151	0.257	0.489
Today's Standards at TSL 4	0.985	1.606	4.067

* Energy savings are in primary energy 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 previously noted, the economic and social considerations in play are broader 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 commercial refrigeration equipment would modify the market.

17.3.5 Early Replacement

Early replacement refers to the replacement of equipment before the end of its 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 commercial refrigeration equipment 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 constitutes the base-case scenario. Because this is the base case, NES and NPV are zero by definition. For comparison, the tables include the results of the NES and NPV at TSL 4 associated with the proposed energy conservation standard.

Table 17.4.1 Cumulative NES of Non-Regulatory Alternatives Compared to the Proposed Standard

Policy Alternatives	Cumulative Primary NES *quads*
No new regulatory action	0
Consumer tax credits	0.151
Customer rebates	0.198
Voluntary energy efficiency targets	0
Early replacement	0
Proposed standards (TSL 4)	0.985

Table 17.4.2 Cumulative NPV of Non-Regulatory Alternatives Compared to the Proposed Standard

Policy Alternatives	Cumulative Net Present Value *billion 2012$*	
	7% Discount	**3% Discount**
No new regulatory action	0	0
Consumer tax credits	0.257	0.489
Customer rebates	0.055	0.122
Voluntary energy efficiency targets	0	0
Early replacement	0	0
Proposed standards (TSL 4)	1.606	4.067

As shown in Table 17.4.1 and Table 17.4.2, 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. In addition, 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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