

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

### TABLE OF CONTENTS

8.1	INTRODUCTION.....	8-1
8.1.1	General Approach for Life-Cycle Cost and Payback Period Analysis.....	8-1
8.1.2	Overview of Life-Cycle Cost and Payback Period Inputs.....	8-2
8.2	LIFE-CYCLE COST INPUTS.....	8-5
8.2.1	Definition.....	8-5
8.2.2	Total Installed Cost Inputs.....	8-5
8.2.2.1	Baseline Manufacturer Selling Price.....	8-6
8.2.2.2	Standard-Level Manufacturer Selling Price Increases.....	8-8
8.2.2.3	Overall Markup.....	8-9
8.2.2.4	Installation Cost.....	8-10
8.2.2.5	Weighted-Average Total Installed Cost.....	8-11
8.2.3	Operating Cost Inputs.....	8-14
8.2.3.1	Electricity Price Analysis.....	8-15
8.2.3.2	Electricity Price Trend.....	8-18
8.2.3.3	Repair Cost.....	8-18
8.2.3.4	Maintenance Cost.....	8-20
8.2.3.5	Lifetime.....	8-23
8.2.3.6	Discount Rate.....	8-23
8.2.3.7	Effective Date of Standard.....	8-26
8.3	PAYBACK PERIOD INPUTS.....	8-28
8.3.1	Definition.....	8-28
8.3.2	Inputs.....	8-28
8.4	LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS.....	8-28
8.4.1	Life-Cycle Cost Results.....	8-28
8.4.1.1	Life-Cycle Cost Breakdown Based on Average Input Values.....	8-29
8.4.1.2	Differences in Life-Cycle Cost Between Baseline and Standard-Level Equipment.....	8-30
8.4.2	Payback Period Results.....	8-32
8.4.3	Rebuttable Presumption Payback Period.....	8-36
8.5	LCC SENSITIVITY STUDIES.....	8-37
8.5.1	Sensitivity to Fuel Escalation Rate.....	8-37
8.5.2	Sensitivity to Baseline Efficiency Level.....	8-39
8.6	DETAILED RESULTS.....	8-41
	REFERENCES.....	8-42

## LIST OF TABLES

Table 8.1.1	Summary Information of Inputs for the Determination of Life-Cycle Cost and Payback Period.....	8-4
Table 8.2.1	Inputs for Total Installed Costs.....	8-6
Table 8.2.2	Products Evaluated for the Commercial Refrigeration Equipment Standard Life-Cycle Cost and Payback Period Analysis .....	8-7
Table 8.2.3	Baseline Efficiency Levels for Commercial Refrigeration Equipment Considered in the Life-Cycle Cost and Payback Period Analysis .....	8-7
Table 8.2.4	Baseline Manufacturer Selling Prices per Unit.....	8-8
Table 8.2.5	Standard-Level Manufacturer Selling Price Increases (Price Increases Relative to the Price of Level 1 Equipment).....	8-9
Table 8.2.6	Installation Costs for Baseline Commercial Refrigeration Equipment Units ....	8-11
Table 8.2.7	Installation Cost Indices (National Value = 100.0) .....	8-12
Table 8.2.8	Costs and Markups for Determination of Weighted-Average Total Installed Costs for Supermarkets (Vertical Open, Remote Condensing, Medium Temperature Case)* .....	8-12
Table 8.2.9	Weighted-Average Equipment Price, Installation Cost, and Total Installed Costs for Vertical Open Refrigerated Display Case, Remote Condensing, Medium Temperature in a Supermarket at U.S. Average Prices (2007\$)* .....	8-14
Table 8.2.10	Inputs for Operating Costs .....	8-15
Table 8.2.11	Estimated Commercial Electricity Prices by State (2007 cents/kWh).....	8-16
Table 8.2.12	Derived Average Commercial Electricity Price by Business Type .....	8-17
Table 8.2.13	Frequency of Component Replacement.....	8-20
Table 8.2.14	Annualized Lighting Maintenance Costs for Each Efficiency Level Addressed in the Life-Cycle Cost Analysis (2007\$) .....	8-22
Table 8.2.15	Annualized Maintenance Costs for Baseline Efficient Commercial Refrigeration Equipment (2007\$).....	8-23
Table 8.2.16	Discount Rates by Company and Ownership Category.....	8-27
Table 8.4.1	Distribution of Life-Cycle Cost Savings from a Baseline Level (Level 1) by Efficiency Level for VOP.RC.M .....	8-32
Table 8.4.2	Average Life-Cycle Cost Savings from Baseline Level (Level 1) by Efficiency Level and Equipment Class.....	8-33
Table 8.4.3	Summary of Payback Period Results for Vertical Open Display Case, Remote Condensing, Medium Temperature, Efficiency Level 4 .....	8-35
Table 8.4.4	National Average Payback Periods by Efficiency Level and Equipment Class.....	8-36
Table 8.4.5	Rebuttable Presumption Payback Periods by Efficiency Level and Equipment Class .....	8-37
Table 8.5.1	Average Life-Cycle Cost Savings from a Baseline Level (Level 1) by Efficiency Level and Equipment Class – EIA Low Price Scenario.....	8-38
Table 8.5.2	Average Life-Cycle Cost Savings from a Baseline Level (Level 1) by Efficiency Level and Equipment Class – EIA High Price Scenario.....	8-39
Table 8.5.3	Sensitivity of Average Life-Cycle Cost Savings and Payback Period to Selection of Baseline Efficiency Level --VCT.RC.L Equipment Class .....	8-40

## LIST OF FIGURES

Figure 8.1.1	Flow Diagram of Inputs for the Determination of Life-Cycle Cost and Payback Period.....	8-4
Figure 8.2.1	Cumulative Probability Distribution Showing the Electricity Prices Paid by Grocery Store/Food Market Sector (2007\$) .....	8-17
Figure 8.2.2	Electricity Price Trends for Commercial Rates to 2042 .....	8-19
Figure 8.4.1	Effect of the Change in Efficiency Level on Life-Cycle Cost for Vertical Open Display Case, Remote Condensing, Medium Temperature in Supermarkets (2007\$) at Average U.S. Conditions (Level 1 is the Baseline Level). .....	8-30
Figure 8.4.2	Cumulative Chart of Life-Cycle Cost Savings for Vertical Open Display Case, Remote Condensing, Medium Temperature: Efficiency Level 4 .....	8-31
Figure 8.4.3	Effect of the Change in Efficiency Level on Payback Period for Vertical Open Display Case, Remote Condensing, Medium Temperature, in Supermarkets at Average U.S. Conditions (Level 1 is the Baseline Level). .....	8-34
Figure 8.4.4	Cumulative Chart of Payback Period for Vertical Open Display Case, Remote Condensing, Medium Temperature: Efficiency Level 4 .....	8-35
Figure 8.5.1	Sensitivity of Payback Period to Baseline Efficiency Level – VCT.RC.L Equipment Class .....	8-41



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

### 8.1 INTRODUCTION

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

- **Life-cycle cost (LCC).** The total customer cost over the life of an appliance or equipment, including purchase costs and operating costs (which in turn include maintenance, repair, and energy costs). Future operating costs are discounted to the time of purchase, and summed over the lifetime of the appliance or equipment.
- **Payback period (PBP).** The amount of time it takes customers to recover the assumed higher purchase price of more energy efficient equipment through lower operating costs.

Inputs to the LCC and PBP analysis of commercial refrigeration equipment are discussed in sections 8.2 and 8.3, respectively. Results for each metric are presented in sections 8.4.1 and 8.4.2, respectively. Key variables and calculations are presented for each metric. The calculations discussed here were performed with a series of Microsoft Excel spreadsheets which are accessible over the Internet

([http://www1.eere.energy.gov/buildings/appliance\\_standards/commercial\\_products.html](http://www1.eere.energy.gov/buildings/appliance_standards/commercial_products.html)).

Details and instructions for using the spreadsheets are discussed in Appendix E. A more complete set of results is presented in Appendix G.

#### 8.1.1 General Approach for Life-Cycle Cost and Payback Period Analysis

Recognizing that each commercial building that uses the commercial refrigeration equipment is unique, DOE analyzed variability and uncertainty by performing the LCC and PBP calculations detailed here for two prototype commercial buildings (stores) and four types of businesses (two types of businesses for each prototype store). The first store prototype is a “large” grocery store, which encompasses (1) supermarkets and (2) wholesaler/retailer multi-line stores, such as “big-box,” “warehouse,” and “supercenters.” The second prototype is a “small” store, which encompasses (1) convenience and small specialty stores, such as meat markets, wine, beer, and liquor stores; and (2) convenience stores associated with gasoline stations. Within a given prototype of stores, one CRE unit of various types can serve the store’s refrigeration needs. The LCC and PBP model was developed using Microsoft Excel spreadsheets.

Aside from the relationship between increasing selling price and increasing energy efficiency, the most important factors influencing the LCC and PBP analysis are related to the State to which each CRE unit is shipped. These factors include energy prices, installation cost, markup, and sales tax. The LCC analysis presented here used the predicted energy consumption based on the engineering analysis and reviewed in chapter 7, Energy Use Characterization.

Energy consumption of commercial refrigeration equipment calculated using this approach is not sensitive to climatic conditions, so energy consumption in the LCC analysis is not assumed to vary by geographical location. Analysis presented in chapter 5, Engineering Analysis, and chapter 7, Energy Use and Load Characterization, explores variation in energy consumption for commercial refrigeration equipment by climate. At the national level, the spreadsheets explicitly modeled variability in the model inputs for electricity price and markups using probability distributions based on the shipment of units to different states and business types.

The LCC and PBP results are displayed as distributions of impacts compared to the baseline conditions, which for purposes of the Final Rule are the Level 1 efficiency level (see section 8.2.2.1 for a description of the efficiency levels). Results are presented at the end of this chapter and in Appendix G of the technical support document (TSD). A variety of graphic displays can be created to illustrate the implications of the analysis. Examples of graphic displays are a cumulative probability distribution showing the percentage of CRE units in U.S. commercial buildings that would experience a net savings at each efficiency level, and a frequency chart depicting variation in life-cycle cost for each CRE efficiency level considered.

### **8.1.2 Overview of Life-Cycle Cost and Payback Period Inputs**

The LCC is the total customer cost over the life of the equipment, including purchase cost and operating cost (including energy cost). Future operating costs are discounted to the time of purchase and summed over the lifetime of the equipment. The PBP is the change in purchase cost due to an increased efficiency standard divided by the change in annual operating cost that results from the standard. It represents the number of years it will take the customer to recover the increased purchase cost through decreased operating costs. In the calculation of PBP, future costs are not discounted.

Inputs to the LCC and PBP analysis are categorized as follows: inputs for establishing the purchase cost, otherwise known as the total installed cost; and inputs for calculating the operating cost (i.e., energy, maintenance, and repair costs).

The primary inputs for establishing the total installed cost are:

- *Baseline manufacturer selling price*: Baseline manufacturer selling price is the price charged by the manufacturer to either a wholesaler or customer for equipment meeting existing minimum efficiency (or baseline) standards. The manufacturer selling price includes a markup that converts the cost (i.e., the manufacturer cost) to a manufacturer selling price.
- *Standard-level manufacturer selling price increase*: Standard-level manufacturer selling price increase is the incremental change in manufacturer selling price associated with producing equipment at each of the higher standard levels.
- *Markups and sales tax*: Markups and sales tax are the markups and sales tax associated with converting the manufacturer selling price to a customer price. The markups and sales tax are described in detail in chapter 6, Markups for Equipment Price Determination.

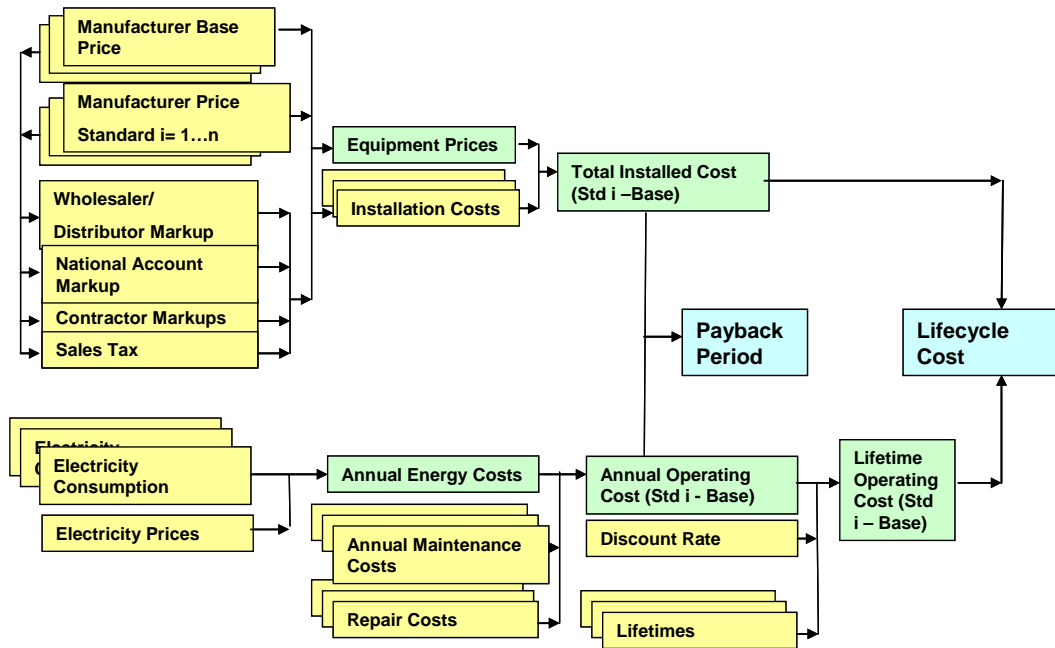
- *Installation price:* Installation price is the cost to the customer of installing the equipment. The installation price represents all costs required to install the equipment but does not include the marked-up customer equipment price. The installation price includes labor, overhead, and any miscellaneous materials and parts. Thus, the total installed cost equals the customer equipment price plus the installation price.

The primary inputs for calculating the operating cost are:

- *Equipment energy consumption:* The equipment energy consumption is the site energy use associated with the use of the commercial refrigeration equipment. Although there are potentially some interactive effects on the overall heating and cooling of the building, for purposes of the Final Rule the LCC analysis includes only the use of electricity by the equipment itself. This approach is consistent with most other DOE equipment efficiency rulemakings. Analysis results from whole building simulation of supermarkets suggest that the overall impact of the design options for the refrigerated cases when taken together did not significantly affect the HVAC energy consumption. Details on the refrigeration equipment energy use simulations and their results are provided in chapter 7, Energy Use Characterization.
- *Electricity prices:* Electricity prices used in the analysis are the price per kilowatt-hour in cents or dollars (e.g., \$/kWh) paid by each customer for electricity. Electricity prices are determined using average commercial electricity prices in each State, as determined from Energy Information Administration (EIA) data for 2007. The 2007 average commercial prices were modified to reflect the fact that the four types of businesses analyzed pay prices that on average are either slightly higher or lower than the average commercial prices. Details on the development of electricity prices and the data sources used are found in Section 8.2.3.1.
- *Electricity price trends:* The EIA's *Annual Energy Outlook 2008*<sup>1</sup> (*AEO 2008*) is used to forecast electricity prices. For the results presented in this chapter, DOE used the *AEO 2008* reference case to forecast future electricity prices.
- *Maintenance costs:* The labor and materials costs associated with maintaining the operation of the equipment (e.g., cleaning heat exchanger coils, checking refrigerant charge levels, lamp replacement).
- *Repair costs:* The labor and materials costs associated with repairing or replacing components that have failed.
- *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 graphically 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 values for the various inputs to the calculation of the LCC and PBP. As noted earlier, most of the inputs are characterized by probability distributions that capture variability in the input. The values provided in Table 8.1.1 are the weighted-average values from the distribution that is being used

to characterize the input. Also listed in Table 8.1.1 are chapters in the TSD where more detailed information on the input can be found.



**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**

Factor	Weighted-Average Value	TSD Reference Section
<b>Total Installed Cost Primary Inputs</b>		
Baseline manufacturer selling price	Varies with product	Chapter 5
Standard-level manufacturer selling price increases	Varies with product and efficiency level	Chapter 5
Markups and sales tax	Varies with product, distribution channel, and location	Chapter 6
Installation price	Varies with location	Chapter 8
<b>Operating Cost Primary Inputs</b>		
Equipment energy consumption	Varies with product	Chapter 7
Electricity prices	Vary with location, building type	Chapter 8
Electricity price trends	Vary with price scenario	Chapter 8
Maintenance costs	Varies with product	Chapter 8
Repair costs	Varies with product	Chapter 8
Lifetime	Varies with type of business	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.

## 8.2 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 (which are comprised of 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:

$$LCC = IC + \sum_{t=1}^N OC_t / (1+r)^t \quad \text{Eq. 8.1}$$

where

$LCC$  = life-cycle cost (\$),  
 $IC$  = total installed cost (\$),  
 $\sum$  = sum over the lifetime, from year 1 to year  $N$ , where  $N$  = lifetime of equipment (years),  
 $OC$  = operating cost (\$),  
 $r$  = discount rate,  
 $t$  = year for which operating cost is being determined.

DOE cost data for the LCC analysis was collected over the 2006-2007 time frame and where necessary the ratio of an appropriate gross domestic product price deflator from 2006 to 2007 was used to provide cost estimates in 2007\$. DOE expresses all the costs in 2007\$ for the LCC analysis. Total installed cost, operating cost, lifetime, and discount rate are discussed in the following sections. In the LCC analysis, the year of equipment purchase is assumed to be 2012.

### 8.2.2 Total Installed Cost Inputs

The total installed cost to the customer is defined by the following equation:

$$IC = EQP + INST \quad \text{Eq. 8.2}$$

where

$EQP$  = equipment price (i.e., customer price for the equipment only) (\$),

$INST$  = installation price or the customer price to install equipment (i.e., the cost for labor and materials), (\$).

The equipment price is based on the distribution channel through which the customer purchases the equipment. As discussed in chapter 6, Markups for Equipment Price Determination, DOE defined three types of distribution channels to describe how the equipment passes from the manufacturer to the customer: the manufacturer sells the equipment to a wholesaler, who in turn sells it to the consumer; the manufacturer sells the equipment to a wholesaler/distributor, who sells to a mechanical contractor, who purchases the equipment on

behalf of the consumer; and the manufacturer sells the equipment directly to the consumer through a national account.

The remainder of this section provides information about the variables 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 (\$)
Standard-level manufacturer selling price increases (\$)
Wholesaler markup
Mechanical contractor markup
National accounts markup
Sales tax (\$)
Installation price (\$)

### 8.2.2.1 Baseline Manufacturer Selling Price

The baseline manufacturer selling price is the price charged by manufacturers to either a wholesaler/distributor or a very large customer for equipment meeting existing minimum efficiency (or baseline) standards. The manufacturer selling price includes a markup that converts the cost to manufacture (i.e., the manufacturing cost) to a manufacturer selling price. DOE developed the baseline manufacturer selling prices through an efficiency level analysis supplemented by certain design option considerations. Refer to chapter 5, Engineering Analysis, for details. DOE developed manufacturer selling prices for equipment classes within ten possible equipment families, with two possible modes of CRE operation (remote condensing and self-contained) and three possible rating temperatures. Not all possible equipment classes have significant actual shipments (see chapter 3, Market and Technology Assessment). The LCC and PBP have been carried out on a set of 15 equipment classes identified in chapter 5. Table 8.2.2 shows the set of 15 equipment classes that DOE evaluated.

DOE was not able to identify a voluntary or industry standard that provided a minimum baseline efficiency requirement or maximum energy consumption level for commercial refrigeration equipment. Although it has been informally reported by the industry that the actual shipments of commercial refrigeration equipment for many of the equipment classes cover a range of efficiencies, no data were identified or made available to DOE. DOE does not have actual shipment data for the various equipment classes by efficiency level and therefore could not define a baseline efficiency level that accurately reflects shipments that may occur across all efficiency levels. Comments received on the ANOPR and NOPR did not provide further detail on the typical or average equipment efficiencies shipped today, although they did suggest modifications of the engineering baseline. Industry representatives stated that they believed use of the engineering baseline was acceptable.<sup>a</sup> Accordingly, for the NOPR, DOE selected the lowest efficiency equipment (Level 1) from the engineering analysis and designated it as the baseline efficiency for the life-cycle cost analysis. That efficiency level has been carried through as the baseline for the Final Rule (Table 8.2.3). The design options incorporated in the Level 1 efficiency level reflected input from CRE manufacturer interviews.

<sup>a</sup> ARI, ANOPR No. 18 at p. 5

**Table 8.2.2 Products Evaluated for the Commercial Refrigeration Equipment Standard Life-Cycle Cost and Payback Period Analysis**

Description (Equipment Family. Operating Mode. Temperature)	Symbol*
Vertical Open.Remote Condensing.Medium Temperature	VOP.RC.M
Vertical Open.Remote Condensing.Low Temperature	VOP.RC.L
Vertical Open.Self Contained.Medium Temperature	VOP.SC.M
Vertical Closed Transparent.Remote Condensing.Medium Temperature	VCT.RC.M
Vertical Closed Transparent.Remote Condensing.Low Temperature	VCT.RC.L
Vertical Closed Transparent.Self Contained.Ice Cream Temperature	VCT.SC.I
Vertical Closed Solid.Self Contained.Ice Cream Temperature	VCS.SC.I
Semi-Vertical Open.Remote Condensing.Medium Temperature	SVO.RC.M
Semi-Vertical Open.Self Contained.Medium Temperature	SVO.SC.M
Service Over Counter.Remote Condensing.Medium Temperature	SOC.RC.M
Horizontal Open.Remote Condensing.Medium Temperature	HZO.RC.M
Horizontal Open.Remote Condensing.Low Temperature	HZO.RC.L
Horizontal Open.Self Contained.Medium Temperature	HZO.SC.M
Horizontal Open.Self Contained.Low Temperature	HZO.SC.L

\* Equipment class designations consist of a combination (in sequential order separated by periods) of 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), an operating mode code (RC=remote condensing or SC=self-contained), and 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. See chapter 3, market and technology assessment, for a more detailed explanation of the equipment class terminology

**Table 8.2.3 Baseline Efficiency Levels for Commercial Refrigeration Equipment Considered in the Life-Cycle Cost and Payback Period Analysis**

Equipment Type	Baseline Energy Consumption (kWh/day)
Vertical Open.Remote Condensing.Medium (VOP.RC.M)	57.9
Vertical Open.Remote Condensing.Low (VOP.RC.L)	133.6
Vertical Open.Self Contained.Medium (VOP.SC.M)	39.6
Vertical Closed Transparent.Remote Condensing.Medium (VCT.RC.M)	33.2
Vertical Closed Transparent.Remote Condensing.Low (VCT.RC.L)	69.3
Vertical Closed Transparent.Self Contained. Ice Cream (VCT.SC.I)	45.6
Vertical Closed Solid.Self Contained.Very Low (VCS.SC.I)	27.1
Semi-Vertical Open.Remote Condensing.Medium (SVO.RC.M)	43.6
Semi-Vertical Open. Self Contained.Medium (SVO.SC.M)	33.1
Service Over Counter.Remote Condensing.Medium (SOC.RC.M)	31.7
Horizontal Open.Remote Condensing.Medium (HZO.RC.M)	19.6
Horizontal Open.Remote Condensing.Low (HZO.RC.L)	38.4
Horizontal Open.Self Contained.Medium (HZO.SC.M)	19.2
Horizontal Open.Self Contained.Low (HZO.SC.L)	38.7
Horizontal Closed Transparent.Self Contained.Ice Cream (HCT.SC.I)	7.2

Table 8.2.4 shows baseline manufacturer selling prices as developed in the engineering analysis. DOE designated the highest-energy-use equipment as Level 1, and selected this as the baseline equipment.

### 8.2.2.2 Standard-Level Manufacturer Selling Price Increases

The standard-level manufacturer selling price increase is the change in manufacturer selling price associated with producing equipment at higher efficiency levels associated with higher standards. DOE developed manufacturer selling price increases associated with increases in equipment efficiency levels through a combination of efficiency level and design option analyses. Refer to chapter 5, Engineering Analysis, for details. Manufacturer selling price increases as a function of equipment efficiency were developed for each of the 15 equipment classes. Although DOE's engineering analysis produced up to 11 efficiency levels, depending on equipment type, only up to eight selected efficiency levels were used in the LCC and PBP analysis. Appendix F discusses the selection of efficiency levels for the LCC and PBP analysis.

**Table 8.2.4 Baseline Manufacturer Selling Prices per Unit**

<b>Equipment Type</b>	<b>Baseline Manufacturer Selling Price (2007\$)</b>
Vertical Open.Remote Condensing.Medium (VOP.RC.M)	\$4,217
Vertical Open.Remote Condensing.Low (VOP.RC.L)	\$6,410
Vertical Open.Self Contained.Medium (VOP.SC.M)	\$2,175
Vertical Closed Transparent.Remote Condensing.Medium (VCT.RC.M)	\$6,710
Vertical Closed Transparent.Remote Condensing.Low (VCT.RC.L)	\$7,356
Vertical Closed Transparent.Self Contained. Ice Cream (VCT.SC.I)	\$3,504
Vertical Closed Solid.Self Contained.Very Low (VCS.SC.I)	\$2,082
Semi Vertical Open.Remote Condensing.Medium (SVO.RC.M)	\$3,804
Semi Vertical Open. Self Contained.Medium (SVO.SC.M)	\$1,778
Service Over Counter.Remote Condensing.Medium (SOC.RC.M)	\$7,465
Horizontal Open.Remote Condensing.Medium (HZO.RC.M)	\$4,265
Horizontal Open.Remote Condensing.Low (HZO.RC.L)	\$4,307
Horizontal Open.Self Contained.Medium (HZO.SC.M)	\$1,586
Horizontal Open.Self Contained.Low (HZO.SC.L)	\$1,849
Horizontal Closed Transparent.Self Contained.Ice Cream (HCT.SC.I)	\$1,036

The engineering analysis established a distribution of manufacturer selling price increases for each standard level. Table 8.2.5 summarizes the estimated manufacturer selling price increases for CRE standard levels considered in the LCC and PBP analysis.

**Table 8.2.5 Standard-Level Manufacturer Selling Price Increases (Price Increases Relative to the Price of Level 1 Equipment)**

Equipment Type	Increase in Manufacturer Selling Price by Efficiency Level						
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	\$34.10	\$116.35	\$201.73	\$451.40	\$504.58	\$4,242.15	NA
VOP.RC.L	\$79.57	\$271.49	\$565.43	\$602.02	\$655.20	\$1,638.00	NA
VOP.SC.M	\$23.74	\$68.21	\$152.41	\$224.67	\$499.41	\$552.58	\$1,785.96
VCT.RC.M	\$28.42	\$96.96	\$665.36	\$1,676.41	\$1,729.58	\$1,795.91	NA
VCT.RC.L	\$28.42	\$96.96	\$1,380.84	\$1,949.23	\$2,002.41	\$2,114.23	NA
VCT.SC.I	\$29.22	\$108.93	\$316.24	\$829.79	\$1,000.41	\$1,011.77	\$1,092.37
VCS.SC.I	\$11.37	\$25.54	\$52.96	\$79.31	\$176.66	\$229.84	\$257.25
SVO.RC.M	\$22.74	\$77.57	\$138.55	\$312.61	\$365.79	\$3,087.07	NA
SVO.SC.M	\$17.32	\$36.71	\$101.06	\$136.44	\$346.41	\$399.58	\$1,300.43
SOC.RC.M	\$22.74	\$77.57	\$138.55	\$202.14	\$2,201.25	\$2,254.42	\$2,559.34
HZO.RC.M	\$22.74	\$77.57	\$155.67	\$208.85	NA	NA	NA
HZO.RC.L	\$22.74	\$77.57	\$173.72	\$226.90	NA	NA	NA
HZO.SC.M	\$8.16	\$13.84	\$33.23	\$67.66	\$179.99	\$193.69	\$246.87
HZO.SC.L	\$15.98	\$21.67	\$95.12	\$100.80	\$295.73	\$309.44	\$362.61
HCT.SC.I	\$8.36	\$14.04	\$121.03	\$134.74	\$187.92	NA	NA

\* NA means that no efficiency level was designated; e.g., VOP.RC.M had only seven efficiency levels and HZO.RC.L had only five.

### 8.2.2.3 Overall Markup

For a given distribution channel, the overall markup is the value determined by multiplying all the associated retail markups and the applicable sales tax markup together to arrive at a single overall distribution chain markup value. The overall markup in turn is multiplied by the baseline or standard-level manufacturer selling price to arrive at the price paid by the customer. Because there are baseline and incremental markups associated with the wholesaler and mechanical contractor, the overall markup is also composed of a baseline markup (i.e., a markup used to convert the baseline manufacturer selling price into a customer price) and an incremental markup (i.e., a markup used to convert a standard-level manufacturer selling price increase due to an increase in rated efficiency into an incremental customer price).

As discussed in chapter 6, Markups for Equipment Price Determination, DOE based overall markups on one of three distribution channels, as well as whether the equipment is being purchased for the new construction or the replacement market. DOE based a distribution channel on whether equipment is purchased either through a wholesaler/distributor, mechanical contractor, or national account.

Based on input received by DOE during the ANOPR comment period, approximately 15 percent of remote-condensing equipment purchased by end-use customers is from wholesaler/distributors, 15 percent is from mechanical contractors, and 70 percent is through national accounts. For self-contained equipment approximately 35 percent of equipment purchased by end-use customers is from wholesaler/distributors, 35 percent is from mechanical contractors, and 30 percent is through national accounts. DOE's understanding is that most existing equipment replacements are done through store remodels (as opposed to equipment failure), and that the distribution channels and installation process are similar for the new and replacement markets. DOE has assumed that the fraction of equipment purchased through the distribution channels is the same for new and replacement equipment. With three distribution channels, there are a total of six overall baseline and incremental markups possible for remote-condensing equipment and an additional six overall baseline and incremental markups for self-

contained equipment. Chapter 6 presented the overall weighted average markups and their associated components for the baseline and incremental markups for both remote-condensing and self-contained equipment for supermarkets. The overall weighted-average baseline markup for supermarkets equals 1.490 for remote-condensing equipment and 1.742 for self-contained equipment. The overall weighted-average incremental markup equals 1.183 for remote-condensing equipment and 1.260 for self-contained equipment. DOE calculated similar markups for the three other building types.

#### **8.2.2.4 Installation Cost**

Most refrigerated display cases are installed in fairly standard configurations, which help in estimating the cost of installation. For example, supermarkets commonly configure such display cases as part of a “line-up” of similar cases. Horizontal open cases are commonly installed as single units placed in appropriate store locations. Self-contained cases are used for portable or temporary product displays, or sometimes used as end-caps of aisles.

Typical steps in the installation of refrigerated display cases in a lineup are as follows:<sup>2</sup>

- 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.

The installation cost is the price to the customer of labor and materials (other than the actual equipment) needed to install the refrigeration equipment. Estimated installation costs for remote-condensing and for self-contained equipment were provided by stakeholders during the ANOPR review period. The majority of the installation price is captured by cost-based labor rates. Labor rates vary significantly from region to region of the country and the *RS Means* data provide the necessary information to capture this regional variability. *RS Means* provides cost indices that reflect the labor rates for 295 cities in the United States. Several cities in all 50 states and the District of Columbia are identified in the *RS Means* data. DOE incorporated these cost indices into the analysis to capture variation in installation cost, depending on the location of the customer.

Since data were not available to indicate how installation costs actually vary with CRE type or efficiency level, DOE considered two scenarios where installation costs either varied in direct proportion to the cost of the equipment, or remained flat (not varying with cost of the equipment). DOE did not however find a basis for the former view, and stakeholder comment during the ANOPR comment period suggested that a flat installation cost was most representative and thus a flat installation price forms the basis of DOE’s LCC calculations. The LCC spreadsheet however, retains the ability to analyze the alternative scenario—that the installation price increases with higher efficiency levels—implemented in the LCC spreadsheet by providing for an installation price that varies in proportion to increased manufacturer cost above the baseline level.

Table 8.2.6 summarizes the national average installation price used by DOE.

**Table 8.2.6 Installation Costs for Baseline Commercial Refrigeration Equipment Units**

<b>System Type</b>	<b>Total Installation Price</b>
Remote Condensing Equipment	\$2,000
Self-Contained Equipment	\$750

Table 8.2.7 summarizes the cost indices for installations in each of the 50 states, plus the District of Columbia, used to vary the nationally representative installation costs in Table 8.2.6.

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 population weights for the year 2000 from the U.S. Census Bureau to calculate a weighted-average index for each state from the *R.S. Means* data. For each business type (e.g., supermarkets) being examined, these state indices are then renormalized based on the proportion of sales to each state for a given business type.

#### **8.2.2.5 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 price. DOE derived the customer equipment price for any given standard level by multiplying the baseline manufacturer selling price by the baseline markup and adding to it the product of the incremental manufacturer selling price and the incremental markup. Because manufacturer selling prices, markups, and the sales tax all can take on a variety of values, depending on location, the resulting total installed cost for a particular standard level will not be a single-point value, but rather a distribution of values.

As an example, the weighted-average costs for the VOP.RC.M equipment class are presented for the baseline level at national average markup rates and national average installation costs. The section also applies the corresponding incremental values to provide an indication of the increase in the total installed cost due to an increase in rated energy efficiency.

**Table 8.2.7 Installation Cost Indices (National Value = 100.0)**

State	Index	State	Index	State	Index
Alabama	65.4	Kentucky	73.2	North Dakota	67.0
Alaska	117.1	Louisiana	60.9	Ohio	103.0
Arizona	79.1	Maine	76.9	Oklahoma	67.3
Arkansas	53.7	Maryland	92.1	Oregon	115.3
California	123.8	Massachusetts	123.1	Pennsylvania	128.5
Colorado	88.3	Michigan	112.3	Rhode Island	120.9
Connecticut	111.7	Minnesota	122.8	South Carolina	42.6
Delaware	125.1	Mississippi	41.6	South Dakota	40.1
Dist. of Columbia	97.7	Missouri	104.0	Tennessee	75.2
Florida	64.8	Montana	80.9	Texas	66.7
Georgia	67.3	Nebraska	83.7	Utah	76.6
Hawaii	126.6	Nevada	113.1	Vermont	73.6
Idaho	78.5	New Hampshire	91.9	Virginia	70.8
Illinois	129.1	New Jersey	132.3	Washington	109.8
Indiana	91.7	New Mexico	78.3	West Virginia	93.5
Iowa	85.6	New York	166.3	Wisconsin	99.3
Kansas	75.0	North Carolina	46.4	Wyoming	56.4

Derivation of the total installed cost is straightforward. The baseline manufacturer selling price and the standard-level manufacturer selling price 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 manufacturer selling prices into total installed costs for a case where the incremental installation costs are held flat. Table 8.2.8 summarizes the weighted average or mean costs and markups necessary for determining the weighted-average baseline and standard-level total installed costs for supermarkets as an example.

**Table 8.2.8 Costs and Markups for Determination of Weighted-Average Total Installed Costs for Supermarkets (Vertical Open, Remote Condensing, Medium Temperature Case)\***

Variable	Weighted Average or Mean Value
Baseline Manufacturer selling price	\$4,217
Standard-Level Manufacturer Selling Price Increase (Efficiency Level 4)	\$202
Overall Markup Factor–Baseline	1.440
Overall Markup Factor–Incremental	1.189
Installation Cost–Baseline	\$2,000
Installation Cost Factor	0.98**

\* Incremental installation costs held flat.

\*\* National incremental cost index on a sales-weighted national basis is not quite equal to 1.00.

To illustrate the derivation of the weighted-average total installed cost shown in Table 8.2.8, DOE presents the calculation below for the baseline (Level 1) and for a higher efficiency level (Level 4) vertical open remote-condensing medium temperature equipment class (VOP.RC.M). For the baseline product, the calculation of the total installed cost at national average conditions is as follows:

$$\begin{aligned}
IC_{BASE\ VOP.RC.M} &= EQP_{BASE\ VOP.RC.M} + INST_{BASE\ VOP.RC.M} \times ISTINDEX && \text{Eq. 8.3} \\
&= MFG_{BASE\ VOP.RC.M} \times MU_{BASE\ VOP.RC.M} + INST_{BASE\ VOP.RC.M} \times \\
&\quad ISTINDEX \\
&= \$4,217 \times (1.440) + \$2,000 \times (0.98) \\
&= \$6,072 + \$2,000 \times (0.98) \\
&= \$8,032
\end{aligned}$$

where

*IC* = total installed cost (\$),  
*EQP* = equipment price (\$),  
*INST* = installation cost or the customer price to install equipment (\$),  
*MFG* = manufacturer selling price (\$),  
*MU* = markup.

In this specific example, *MFG* is the national average baseline manufacturer selling price for the VOP.RC.M equipment class and *MU* is the overall baseline markup. The calculation of the higher efficiency Level 4 total installed cost includes the use of a manufacturer selling price adder. In addition, DOE derived an incremental markup.

In view of incremental equipment price changes, DOE based the derivation of the Level 4 total installed cost on determining the change in equipment price over the baseline equipment price. The manufacturer selling price increment for a higher efficiency level is multiplied times the incremental markup.

DOE calculated the Level 4 total installed cost (*IC*<sub>VOP.RC.M LEVEL4</sub>) as follows:

$$\begin{aligned}
IC_{VOP.RC.M\ LEVEL4} &= EQP_{VOP.RC.M\ LEVEL4} + \Delta EQP_{VOP.RC.M\ LEVEL4} + INST_{VOP.RC.M\ LEVEL4} && \text{Eq. 8.4} \\
&= MFG_{BASE\ VOP.RC.M} \times MU_{BASE\ VOP.RC.M} + \Delta MFG_{VOP.RC.M\ LEVEL4} \\
&\quad \times MU_{VOP.RC.M\ LEVEL4} + INST \times ISTINDEX \\
&= \$4,217 \times (1.440) + \$202 \times (1.189) + \$2,000 \times (0.98) \\
&= \$8,273
\end{aligned}$$

where

*IC* = total installed cost (\$),  
*EQP* = equipment price (\$),  
*INST* = installation cost or the customer price to install equipment (\$),  
*MFG* = manufacturer selling price (\$),  
*MU* = markup,  
*ISTINDEX* = location dependent multiplier on installation costs, but approximately 1.0 at a national average.

Table 8.2.9 presents the weighted-average equipment price, installation costs, and total installed costs for the VOP.RC.M equipment classes at the baseline level and each higher efficiency level examined.

**Table 8.2.9 Weighted-Average Equipment Price, Installation Cost, and Total Installed Costs for Vertical Open Refrigerated Display Case, Remote Condensing, Medium Temperature in a Supermarket at U.S. Average Prices (2007\$)\***

Efficiency Level	Equipment Price	Installation Cost	Total Installed Cost
1 (Baseline)	\$6,074	\$1,960	\$8,036
2	\$6,115	\$1,960	\$8,076
3	\$6,213	\$1,960	\$8,174
4	\$6,314	\$1,960	\$8,275
5	\$6,611	\$1,960	\$8,572
6	\$6,674	\$1,960	\$8,636
7	\$11,119	\$1,960	\$13,081
8	NA	NA	NA

\*Details do not add to total due to rounding error, Total is exact.

### 8.2.3 Operating Cost Inputs

DOE based the operating cost for the LCC analysis on energy consumption data developed from whole-building simulations on a sample of buildings from the 2003 Commercial Buildings Energy Consumption Survey (CBECS).<sup>3</sup> After the LCC analysis was performed, DOE generated a distribution of LCC differences (i.e., the LCC difference between the baseline equipment and equipment with a higher efficiency level) to determine the mean LCC difference, as well as the percentage of buildings analyzed that had LCC savings associated with more efficient equipment.

DOE defined the operating cost by the following equation:

$$OC = EC + RC + MC \quad \text{Eq. 8.5}$$

where

- OC* = operating cost (\$),
- EC* = energy cost associated with operating the equipment (\$),
- RC* = repair cost associated with component failure (\$),
- MC* = service cost for maintaining equipment operation (\$).

The remainder of this section provides information about the variables that DOE used to calculate the operating cost for commercial refrigeration equipment.

Table 8.2.10 shows the inputs for the determination of operating costs. The lifetime, discount rate, and effective date of the standard are required for determining the operating cost and for establishing the operating cost present value. The electricity consumption for the baseline (which by definition is efficiency Level 1 for the Final Rule) and the other efficiency levels examined (efficiency levels 2, 3, etc.) define the efficiency levels of interest for comparing standards' life operating costs.

**Table 8.2.10 Inputs for Operating Costs**

Electricity price (\$)
Electricity price trend
Repair cost (\$)
Maintenance cost (\$)
Lifetime (years)
Discount rate (percent)
Effective date of standard
Baseline electricity consumption (kWh/day)
Standard case electricity consumption (kWh/day)

### 8.2.3.1 Electricity Price Analysis

**Introduction to the analysis of electricity prices.** This section describes the electricity price (cents/kWh) analysis used to develop the energy portion of the annual operating costs (price times electricity consumption) for commercial refrigeration equipment in the grocery sector.

**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 continental U.S. into the 50 states and the District of Columbia. DOE used reported average effective commercial electricity prices at the state level from the EIA Form EIA-826 Database Monthly Electric Utility Sales and Revenue Data ("EIA-826 Sales and Revenue Spreadsheets) database.<sup>4</sup> The latest available prices from this source are for the calendar year 2006. These were adjusted to represent 2007\$ prices using the forecasted ratio between 2007 and 2006 national commercial retail electricity prices from the *2007 Annual Energy Outlook*.

$$EPRICE_{COM STATE 2007} = EPRICE_{COM STATE 2006} \times (EPRICE_{COM AEO FORECAST 2007} / EPRICE_{COM AEO FORECAST 2006}) \quad \text{Eq. 8.6}$$

where

$EPRICE_{COM STATE YEAR}$  = commercial sector average electricity price in a state or United States (US) in a particular year (cents/kWh),

$EPRICE_{COM AEO FORECAST YEAR}$  = commercial sector reference case national average forecasted electricity price in a specific year from the *2007 Annual Energy Outlook* (cents/kWh).

Table 8.2.11 provides data on the adjusted electricity prices.

**Table 8.2.11 Estimated Commercial Electricity Prices by State (2007 cents/kWh)**

State	Commercial Electricity Price	State	Commercial Electricity Price	State	Commercial Electricity Price
Alabama	8.70	Kentucky	6.65	North Dakota	6.53
Alaska	11.93	Louisiana	9.17	Ohio	8.63
Arizona	8.25	Maine	13.12	Oklahoma	7.30
Arkansas	6.88	Maryland	11.51	Oregon	7.23
California	12.76	Massachusetts	15.12	Pennsylvania	9.18
Colorado	7.60	Michigan	8.95	Rhode Island	12.78
Connecticut	15.26	Minnesota	7.39	South Carolina	7.73
Delaware	11.22	Mississippi	8.95	South Dakota	6.54
Dist. of Col.	12.32	Missouri	6.25	Tennessee	7.99
Florida	9.69	Montana	7.95	Texas	10.00
Georgia	8.04	Nebraska	6.28	Utah	6.54
Hawaii	21.92	Nevada	10.10	Vermont	12.25
Idaho	5.13	New Hampshire	13.83	Virginia	6.40
Illinois	9.14	New Jersey	13.26	Washington	6.55
Indiana	7.20	New Mexico	7.64	West Virginia	5.78
Iowa	7.06	New York	15.44	Wisconsin	8.61
Kansas	6.90	North Carolina	7.41	Wyoming	6.20

Furthermore, 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 CBECS data set to identify the average prices paid by the four kinds of businesses in this analysis compared with the average prices paid by all commercial customers. Equation 8.7 shows the ratios of prices paid by the four types of businesses were used to increase or decrease the average commercial prices.

$$EPRICE_{COM\ BLD\ I\ STATE\ 2006} = EPRICE_{COM\ STATE\ 2006} \times (EPRICE_{BLDG\ I\ US\ 2003} / EPRICE_{COM\ US\ 2003}) \quad \text{Eq. 8.7}$$

where

$EPRICE_{COM\ BLD\ I\ STATE\ 2006}$  = average commercial sector electricity price in building type I (supermarkets) in a specific state in 2006 (cents/kWh),

$EPRICE_{COM\ STATE\ 2006}$  = average commercial sector electricity price in a specific state in 2006 (cents/kWh),

$EPRICE_{BLDG\ I\ US\ 2003}$  = national average commercial sector electricity price in building type I in 2003 CBECS (cents/kWh),

$EPRICE_{COM\ US\ 2003}$  = national average commercial sector electricity price in 2003 CBECS (cents/kWh).

Table 8.2.12 shows the derivation of the EPRICE ratios from CBECS.

**Table 8.2.12 Derived Average Commercial Electricity Price by Business Type**

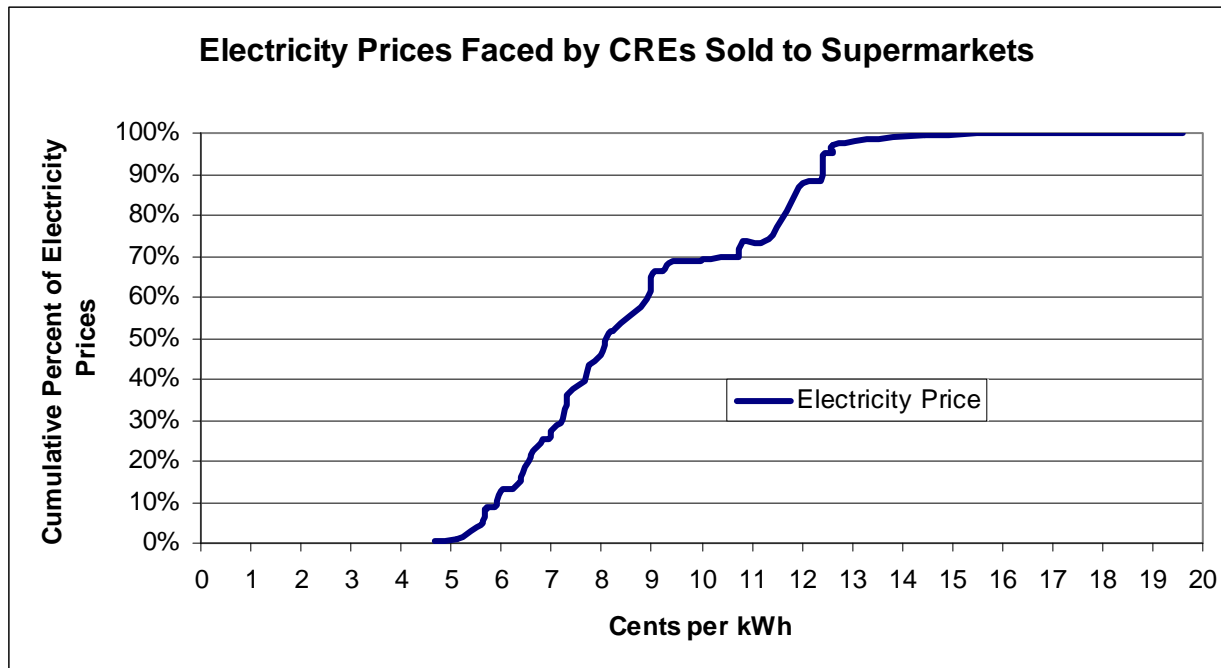
Business Type	Grocery Store/Food Market	Convenience Store*	Convenience Store with Gas Station	Other Food Sales**	All Food Sales	All Commercial Buildings
Electricity Price (cents/kWh)	7.2	8.6	7.7	8.2	7.6	7.8
Ratio of Electricity Price to Average Price for all Commercial Buildings	0.928	1.109	0.993	1.057	0.980	1.000

\* 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 super centers that sell both grocery and non-grocery items.

Source: CBECS 2003

Once the electricity prices for the four commercial building types (stores) were adjusted, DOE used the resulting prices in the analysis to represent 2007 electricity prices. Future prices are 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 estimated sales of CRE units in each state to each prototype building.<sup>5,6,7,8</sup> The state/building type weights are the probabilities that a given CRE unit shipped will be operated with a given price. For evaluation purposes, the prices and weights can be depicted as a cumulative probability distribution. The effective prices range from approximately 5 cents per kWh to approximately 20 cents per kWh. Figure 8.2.1 illustrates the results for the grocery store and food market sector.



**Figure 8.2.1 Cumulative Probability Distribution Showing the Electricity Prices Paid by Grocery Store/Food Market Sector (2007\$)**

### 8.2.3.2 Electricity Price Trend

The electricity price trend provides the relative change in electricity prices for future years out to the year 2030. 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. The discussion in this chapter uses the *AEO 2008* reference price scenario. In the LCC analysis, the following four scenarios can be analyzed:

1. Constant (real) energy prices at 2008 values (Constant index of 1.0 in Figure 8.2.2)
2. *AEO 2008*, High Price Case ("High Price" in Figure 8.2.2)
3. *AEO 2008*, Reference Case ("AEO 2008" in Figure 8.2.2)
4. *AEO 2008*, Low Price Case ("Low Price" in Figure 8.2.2)

Figure 8.2.2 shows the trends for the three *AEO 2008* price projections where prices are assumed to change. DOE extrapolated the values in later years (i.e., after 2030) from their relative sources because *AEO 2008* does not forecast beyond 2030. To arrive at values for these later years, DOE used the price trend from 2020 to 2030 of the forecast to establish prices in the years 2030 to 2042. This method of extrapolation is in line with methods currently used by the EIA to forecast fuel prices for the Federal Energy Management Program.

The default electricity price trend scenario used in the LCC analysis is the trend from the *AEO 2008* 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 *AEO 2008* High Price and the *AEO 2008* Low Price trends and constant energy prices.

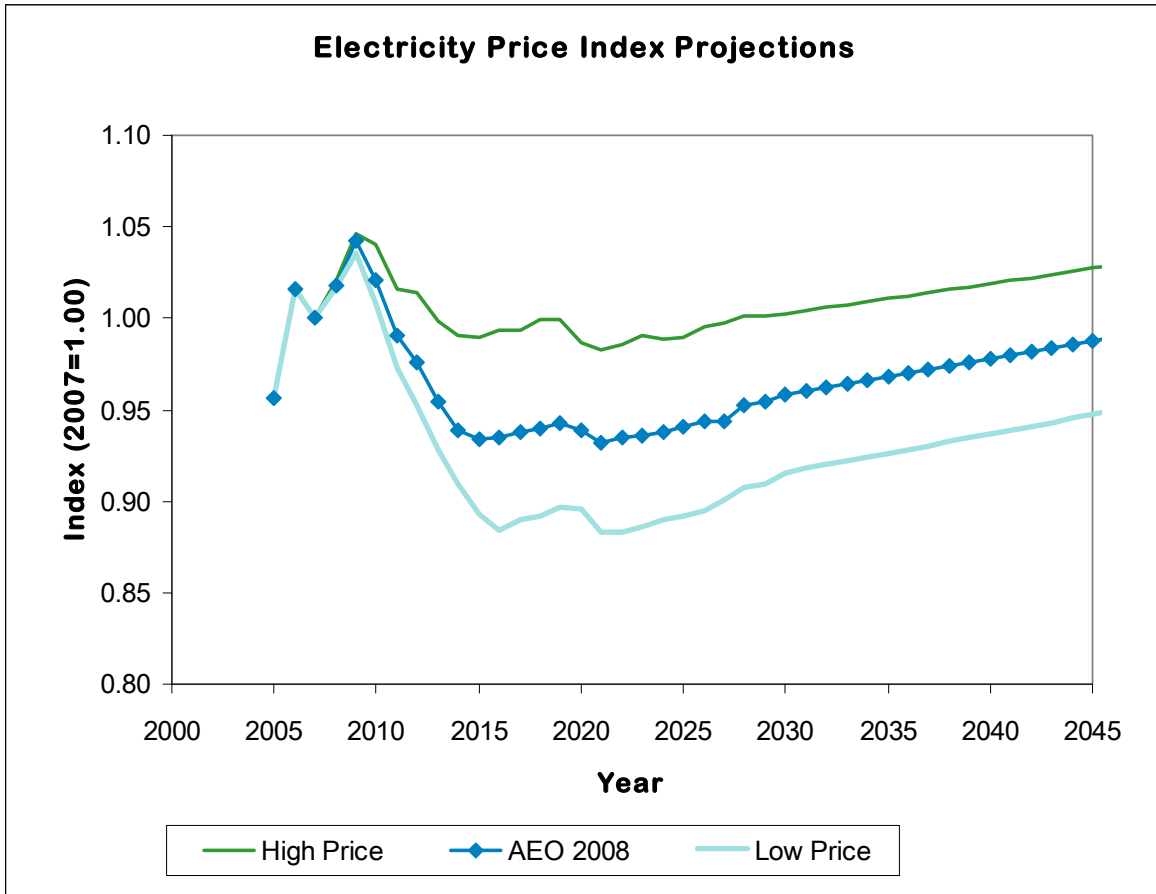
### 8.2.3.3 Repair Cost

The repair cost is the cost to the consumer for replacing or repairing components in the commercial refrigeration equipment that have failed. DOE based the annualized repair cost for baseline energy consumption commercial refrigeration equipment (i.e., the cost the customer pays annually for repairing the equipment) on the following expression:

$$RC = k \times EQP / LIFE \quad \text{Eq 8.8}$$

where

- $RC$  = repair cost (\$),
- $k$  = fraction of the equipment price (a value of 0.5 was assumed),
- $EQP$  = equipment price (customer price for the equipment only) (\$),
- $LIFE$  = average lifetime of the equipment in years (a value of 10.0 years was assumed).



**Figure 8.2.2 Electricity Price Trends for Commercial Rates to 2042**

Data were not available to indicate how repair costs vary with equipment efficiency level, however stakeholder input during the rulemaking indicated that repair costs would likely increase with more efficient equipment due to the use of more expensive components. To estimate how repair costs might vary with equipment efficiencies DOE contacted CRE users to assess typical equipment failure rates in the field and used replacement cost estimates to augment the baseline repair cost established above. This resulted in increasing repair costs for equipment at higher efficiency levels.

Key equipment components that might be replaced over the equipment life and for which higher efficiency components are examined in the engineering analysis are shown in Table 8.2.13 along with estimates of the relative frequency of replacement<sup>b</sup>. Replacement frequencies were annualized for use in the LCC analysis in order to develop lifecycle repair costs for equipment with different operational lifetimes. Costs for replacement components in the field were estimated as 250 percent of the OEM cost for each component in 2007\$ as established in the engineering analysis.

<sup>b</sup> Estimates for replacement frequencies were based on personal conversation with Jim Vannon, Engineering Manager for Albertsons, October 26, 2007

**Table 8.2.13 Frequency of Component Replacement**

<b>Component</b>	<b>Estimated Replacement Rate (over 10 year period)</b>
Evaporator Fans	50%
Condenser Fans	25%
Compressors	25%
Coils	5%
Doors	5%

#### **8.2.3.4 Maintenance Cost**

The maintenance cost is the cost to the consumer of maintaining equipment operation. The maintenance cost is not the cost associated with the replacement or repair of components that unexpectedly have failed (as discussed above). Rather, it is the cost associated with general maintenance (e.g., checking and maintaining refrigerant charge levels, cleaning heat exchanger coils).

DOE took annualized maintenance costs for commercial refrigeration equipment from data in *RS Means Facilities Maintenance & Repair Cost Data*.<sup>9</sup> *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. DOE did not break out these activities into separate line-item maintenance activities. Instead, DOE used a single figure of \$160/yr (2007\$) for preventative maintenance activities for all CRE classes.

Because data were not available to indicate how maintenance costs vary with equipment efficiency level, DOE decided to use preventative maintenance costs that remain constant as equipment efficiency is increased.

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 CRE classes have different numbers of lamps (and ballasts), and many of the efficiency options DOE considered in its design option engineering analysis involved changes to the lighting configuration (lamp, ballast, or use of light emitting diode (LED) lighting systems). Because the lighting configurations can vary by efficiency level, DOE estimated the relative maintenance costs for lighting by each case type for which DOE performed a design option analysis. 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 2007\$) over the estimated life of the equipment divided by the estimated life of the equipment.

Lifetime estimates for particular 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 over the estimated 10-year life of the equipment based on a typical fixture life of 50,000 hours (GE 2007).<sup>10</sup>

DOE based cost estimates for fluorescent lamp and ballast replacements on review of the original equipment manufacturer (OEM) costs used in the engineering analysis, *RS Means* estimates and cost data from *Grainger*,<sup>11</sup> and previous studies. The final approach taken was to estimate the costs of field replacement using labor cost hours from *RS Means Electrical Cost Data*<sup>12</sup> for typical lamp or ballast replacement for other lighting fixtures, and to provide a 150-percent multiplier on OEM costs for lamps and ballasts (provided in the engineering analysis spreadsheets) to reflect retail pricing.

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. DOE's estimate for the ANOPR was that costs for replacing LED lighting fixtures (which would occur first in approximately 2018, or six years after the target date of the rule) would be 140 percent of the OEM cost of LED case lighting fixtures today (in 2007\$). DOE recognizes that both life and cost assumptions for LED replacement are speculative and believes it has taken a conservative approach to estimating price reduction over time for this technology. DOE did not consider overhead and profit factors from *RS Means*.

The total costs for lamp, ballast or LED fixture replacement were annualized by dividing the total estimated replacement costs over the CRE lifetime as shown in Eq. 8.9.

$$\text{Annualized Lighting Maintenance} = \frac{1}{\text{Life}} \sum_{\text{Life}} \left( \text{Bulb \& Ballast}_{OEM} \times 150\% + N_{\text{Bulb}} \times \text{Labor}_{\text{Bulb}} + N_{\text{Ballast}} \times \text{Labor}_{\text{Ballast}} \right) + \text{LED Fixture}_{OEM} \times 140\% \quad \text{Eq. 8.9}$$

where

*Annualized Lighting Maintenance* = Annualized Lighting Maintenance Cost (2007\$),  
*Life* = CRE lifetime (years),  
*Bulb & Ballast<sub>OEM</sub>* = OEM Costs for bulb and ballast from engineering analysis (\$),  
*LED Fixture<sub>OEM</sub>* = OEM Installed costs for LED fixtures from engineering analysis (\$),  
*N<sub>Bulb</sub>* = Number of bulbs in particular CRE class analyzed,  
*N<sub>Ballast</sub>* = Number of ballasts in particular CRE class analyzed,  
*Labor<sub>Bulb</sub>* = Labor cost to replace one bulb (\$),  
*Labor<sub>Ballast</sub>* = Labor cost to replace one ballast (\$).

The Air-Conditioning and Refrigeration Institute provided cost-energy-consumption curves for certain equipment classes, but without maintenance costs for lighting components. For such equipment classes, DOE calculated a nominal lighting maintenance cost for all levels on the basis that T8 lamp lighting represented the current market.<sup>13</sup>

Table 8.2.14 shows the annualized lighting maintenance costs for each efficiency level addressed in the LCC analysis.

**Table 8.2.14 Annualized Lighting Maintenance Costs for Each Efficiency Level Addressed in the Life-Cycle Cost Analysis (2007\$)**

Equipment Type	Annualized Lighting Maintenance Costs (\$/yr)							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	104.37	104.37	104.37	140.12	140.12	140.12	428.83	NA
VOP.RC.L	44.73	44.73	44.73	44.73	60.05	60.05	118.13	NA
VOP.SC.M	38.64	38.64	38.64	38.64	50.86	50.86	50.86	142.94
VCT.RC.M	98.27	98.27	98.27	83.71	83.71	83.71	83.71	NA
VCT.RC.L	98.27	98.27	98.27	83.71	83.71	83.71	83.71	NA
VCT.SC.I	49.14	49.14	49.14	33.70	33.71	33.70	33.70	33.70
VCS.SC.I	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SVO.RC.M	74.55	74.55	74.55	100.08	100.08	100.08	311.78	NA
SVO.SC.M	26.77	26.77	26.77	26.77	35.44	35.44	35.44	103.93
SOC.RC.M	74.55	74.55	74.55	100.08	100.08	235.18	235.18	235.18
HZO.RC.M	0.00	0.00	0.00	0.00	0.00	NA	NA	NA
HZO.RC.L	0.00	0.00	0.00	0.00	0.00	NA	NA	NA
HZO.SC.M	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HZO.SC.L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HCT.SC.I	0.00	0.00	0.00	0.00	0.00	0.00	NA	NA

\*NA means that no efficiency level was designated; e.g., VOP.RC.M had only seven efficiency levels and HZO.RC.L had only five.

Total annualized maintenance costs are the sum of the preventative maintenance and the lighting maintenance costs. Table 8.2.15 summarizes the nationally representative annualized maintenance costs for baseline refrigeration equipment.

**Table 8.2.15 Annualized Maintenance Costs for Baseline Efficient Commercial Refrigeration Equipment (2007\$)**

Equipment Type	Annualized Lighting Maintenance Costs for LCC (\$/yr)							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	260.79	260.79	260.79	296.54	296.54	296.54	585.25	NA
VOP.RC.L	201.15	201.15	201.15	201.15	216.47	216.47	274.55	NA
VOP.SC.M	195.06	195.06	195.06	195.06	207.28	207.28	207.28	299.36
VCT.RC.M	254.69	254.69	254.69	240.13	240.13	240.13	240.13	NA
VCT.RC.L	254.69	254.69	254.69	254.69	240.13	240.13	240.13	NA
VCT.SC.I	205.56	205.56	205.56	190.12	190.12	190.12	190.12	190.12
VCS.SC.I	156.42	156.42	156.42	156.42	156.42	156.42	156.42	156.42
SVO.RC.M	230.97	230.97	230.97	256.50	256.50	256.50	468.20	NA
SVO.SC.M	183.19	183.19	183.19	183.19	191.86	191.86	191.86	260.35
SOC.RC.M	230.97	230.97	230.97	256.50	256.50	391.61	391.61	391.61
HZO.RC.M	156.42	156.42	156.42	156.42	156.42	NA	NA	NA
HZO.RC.L	156.42	156.42	156.42	156.42	156.42	NA	NA	NA
HZO.SC.M	156.42	156.42	156.42	156.42	156.42	156.42	156.42	156.42
HZO.SC.L	156.42	156.42	156.42	156.42	156.42	156.42	156.42	156.42
HCT.SC.I	156.42	156.42	156.42	156.42	156.42	156.42	NA	NA

\*NA means that no efficiency level was designated; e.g., VOP.RC.M had only seven efficiency levels and HZO.RC.L had only five.

### 8.2.3.5 Lifetime

DOE defines lifetime as the age when a CRE unit is retired from service. DOE based equipment lifetime on discussions with industry experts, and concluded that a typical lifetime of 10 years is appropriate for commercial refrigeration equipment used in large grocery and multiline retail business types. Based on comments received during the ANOPR, DOE used 15 year life for commercial refrigeration equipment used in small grocery/convenience stores. Chapter 3, Market and Technology Assessment, contains a discussion of equipment life and tabulates estimates from various sources used in assessing equipment life. CRE units are typically replaced when stores are renovated—about every 10 years for large grocery chains<sup>14</sup>—which is before the CRE units would have physically worn out. Because of this, there is a used-equipment market for commercial refrigeration equipment. DOE understands, however, that the salvage value to the original purchaser is very low and thus this has not been taken into account in the LCC.

### 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 CRE 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).<sup>15</sup> The CAPM, among the most widely used models to estimate the cost of equity financing, assumes that the cost of equity is proportional to the amount of systematic risk associated with a company. The cost of equity financing tends to be high when a company faces a large degree of systematic risk and it tends to be low when the company faces a small degree of systematic risk.

DOE determined the cost of equity financing by using several variables, including the risk coefficient of a company,  $\beta$  (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,  $\beta$ , indicates the degree of risk associated with a given firm relative to the level of risk (or price variability) in the overall stock market. Risk coefficients usually vary between 0.5 and 2.0. A company with a risk coefficient of 0.5 faces half the risk of other stocks in the market; a company with a risk coefficient of 2.0 faces twice the overall stock market risk.

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

$$k_e = R_f + (\beta \times ERP) \quad \text{Eq. 8.10}$$

where

- $k_e$  = the cost of equity for a company, expressed as a percentage,
- $R_f$  = the expected return of the risk free asset, expressed as a percentage,
- $\beta$  = the risk coefficient,
- $ERP$  = the expected equity risk premium, expressed as a percentage.

DOE defined the risk-free rate as the yield (January 2007) on long-term government bonds. DOE used a 4.8-percent estimate for the  $ERP$  based on data from the Damodaran Online<sup>16</sup> site.

The cost of debt financing is the yield or interest rate paid on money borrowed by a company (for example, by selling bonds). As defined here, the cost of debt includes compensation for default risk (the risk that a firm will go bankrupt) and excludes deductions for taxes. DOE estimated the cost of debt for companies by adding a risk adjustment factor to the current yield on long term corporate bonds (the risk free rate). It used this procedure to estimate current (and future) company costs to obtain debt financing. It based the adjustment factor on indicators of company risk, such as credit rating or variability of stock returns.

The weighted-average cost of capital (WACC) of a company is the weighted-average cost of debt and equity financing:

$$k = k_e \times w_e + k_d \times w_d \quad \text{Eq. 8.11}$$

where

- $k$  = the (nominal) cost of capital, expressed as a percentage
- $k_e$  = the expected rate of return on equity, expressed as a percentage,
- $k_d$  = the expected rate of return on debt, expressed as a percentage,
- $w_e$  = the proportion of equity financing in total annual financing,

$w_d$  = the proportion of debt financing in total annual financing.

The cost of capital is a nominal rate, because it includes anticipated future inflation in the expected returns from stocks and bonds. The real discount rate or WACC deducts expected inflation ( $r$ ) from the nominal rate. DOE calculated expected inflation (2.0 percent) from the average of the projected change in gross domestic product (GDP) prices in the *Economic Report of the President* (February 2008).<sup>17</sup>

To estimate the WACC of CRE purchasers, DOE used a sample of companies involved in groceries and multi-line retailing drawn from a database of over 7,300 U.S. companies given on the *Damodaran Online* website. This database includes most of the publicly-traded companies in the United States.

DOE divided the companies into the three ownership categories shown in Table 8.2.16 according to their type of activity (small grocery, in the last line of the table covers convenience stores with and without gasoline stations). DOE sought financial information for all of the firms in the full sample involved in the two lines of business. This resulted in a sample of about 15 firms. In cases where one or more of the variables needed to estimate the discount rate was missing or could not be obtained, DOE discarded the firm from the analysis. Overall, it discarded about 27 percent of the firms in the full database for this reason.

Table 8.2.16 describes the economic sectors represented in each of the ownership categories as well as the number of companies used for determining discount rates.

Ultimately, DOE used a sample of 11 companies to represent the purchasers of commercial refrigeration equipment. For each company in the sample, DOE derived the cost of debt, percent debt financing, and systematic company risk from information provided at the *Damodaran Online* website. It estimated the cost of debt financing from the long-term government bond rate (4.28 percent) and the standard deviation of the stock price. Table 8.2.16 shows the weighted-average values for the cost of debt, percent debt financing and systematic firm risk for each category of the sample companies. 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. Individual credit-worthiness varies considerably, and some franchisees have access to the financial resources of the franchising corporation. However, personal contacts with a sample of commercial bankers yielded an estimate for the small operator weighted cost of capital of about 200 to 300 basis points (2 percent to 3 percent) above the rates for large grocery chains. A central value equal to the weighted average of large grocery chains, plus 2.5 percent, was used for small operators.

Deducting expected inflation from the cost of capital provides the estimates of the real discount rate by ownership category shown in Table 8.2.16. The average after-tax discount rate, weighted by the percentage shares of total CRE purchases, is 5.00 percent for large grocery, 5.24 percent for multi-line retailers and 7.50 percent for convenience stores and convenience stores associated with gasoline stations.

### **8.2.3.7 Effective Date of Standard**

The effective date is the future date when a new standard becomes operative. Under 42 U.S.C. 6313(a)(6)(c), the effective date of any new energy conservation standard for commercial refrigeration equipment will be three years after the Final Rule is published. DOE calculated the LCC for all customers as if they each would purchase a new CRE unit in the year the standard takes effect. Consistent with its published regulatory agenda, DOE assumed that the Final Rule would be issued in 2009 and that, therefore, the new standards would take effect in 2012 and used these dates in the ANOPR analyses. It based the cost of the equipment on this year; however, all dollar values are expressed in 2007\$. DOE considered annual energy for the life of the commercial refrigeration equipment. For the LCC analysis, the year of equipment purchase is 2012.

Table 8.2.16 Discount Rates by Company and Ownership Category

Company	Company Value (millions \$)	Value Line Beta	Cost of Equity (E)	E/(D+E)	Std Dev in Stock	Cost of Debt (D)	Effective Tax Rate	After Tax Cost of Debt	Market Debt to Capital (D/(D+E))	Cost of Capital
A	\$ 470	0.85	8.39%	99.70%	32.21%	5.28%	40.63%	3.13%	0.30%	8.38%
B	\$ 1,770	1.2	10.09%	86.04%	24.28%	4.78%	36.12%	3.05%	13.96%	9.11%
C	\$ 1,651	1.1	9.60%	78.94%	52.57%	5.78%	0.00%	5.78%	21.06%	8.80%
D	\$ 1,179	1.15	9.85%	52.83%	31.37%	5.28%	37.45%	3.30%	47.17%	6.76%
E	\$ 25,157	1	9.12%	71.94%	19.64%	4.53%	36.21%	2.89%	28.06%	7.37%
F	\$ 1,951	1.2	10.09%	87.29%	20.98%	4.78%	36.21%	3.05%	12.71%	9.19%
G	\$ 21,411	0.65	7.43%	72.59%	19.18%	4.53%	37.57%	2.83%	27.41%	6.17%
H	\$ 1,013	1.2	10.09%	95.61%	55.96%	5.78%	43.48%	3.27%	4.39%	9.79%
I	\$ 379	0.85	8.39%	92.79%	28.01%	5.03%	41.92%	2.92%	7.21%	8.00%
J	\$ 1,090	1.25	10.33%	100.00%	15.82%	4.53%	34.94%	2.95%	0.00%	10.33%
K	\$ 5,756	0.9	8.64%	99.85%	33.91%	5.28%	40.00%	3.17%	0.15%	8.63%
Large Grocery Weighted Average		0.89	8.60%	76.69%	22.76%	4.69%	36.26%	3.00%	23.31%	7.31%
			<i>Inflation-Adjusted</i>							<b>5.00%</b>
U	\$ 2,554	0.9	8.64%	93.3%	18.48%	4.53%	36.7%	2.87%	6.66%	8.25%
V	\$ 2,828	1.1	9.60%	81.0%	19.99%	4.53%	38.0%	2.81%	19.00%	8.31%
W	\$ 230,328	0.8	8.15%	83.1%	14.93%	4.53%	33.6%	3.01%	16.94%	7.28%
Large Multi-Line Retailers and Wholesalers Weighted Average		0.89	8.44%	83.78%	16.14%	4.53%	34.63%	2.96%	16.22%	7.55%
Small Grocery, Inflation Adjusted									<i>Inflation-Adjusted</i>	<b>5.24%</b>
										<b>7.50%</b>

E=equity; D=debt

Source: Pacific Northwest National Laboratory (PNNL) calculations applied to firms sampled from the Damodaran Online website.

## 8.3 PAYBACK PERIOD INPUTS

### 8.3.1 Definition

The payback period is the amount of time it takes the consumer to recover the assumed higher purchase cost of more energy-efficient equipment as a result of lower operating costs. Numerically, the PBP is the ratio of the increase in purchase cost (i.e., from a less efficient design to a more efficient design) to the decrease in annual operating expenditures. This type of calculation is known as a “simple” 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:

$$PBP = \Delta IC / \Delta OC \quad \text{Eq. 8.12}$$

where

$PBP$  = payback period (years),

$\Delta IC$  = difference in the total installed cost between the more efficient standard level, equipment (efficiency Levels 2, 3, etc.) and the baseline (efficiency Level 1) equipment (\$),

$\Delta OC$  = difference in annual operating costs (\$).

Payback periods are expressed in years. Payback periods greater than the life of the product mean that the increased total installed cost of the more efficient equipment is not 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 efficiency level and the annual (first year) operating costs for each efficiency level. 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 uses the same inputs as the LCC analysis described in section 8.2, except that electricity price trends and discount rates are not required. Since the PBP is a “simple” (undiscounted) payback, the required electricity cost is only for the year in which a new efficiency standard is to take effect—in this case, the year 2012. The electricity price used in the PBP calculation of electricity cost was the price projected for 2012, expressed in 2007\$, but not discounted to 2007. Discount rates are not used in the PBP calculation.

## 8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

### 8.4.1 Life-Cycle Cost Results

This section presents LCC results for the higher efficiency levels specified in the engineering analysis (chapter 5) and also presented in section 8.2.2.2, Standard-Level Manufacturer Selling Price Increases. The results presented here are based on annual operating

costs calculated from average annual electricity prices developed for each business type. Section 8.2 presents the electricity price inputs as well as all other LCC inputs.

Because the values of most inputs are variable in this analysis, DOE represents them as a distribution of values rather than a single point-value. Thus, DOE represents the LCC results as a distribution of values. Before proceeding with the presentation of the distribution of LCC results, DOE presents average values for total installed costs, annual operating costs, and LCC to show how these costs vary with efficiency level for each of the commercial refrigeration equipment classes.

#### **8.4.1.1 Life-Cycle Cost Breakdown Based on Average Input Values**

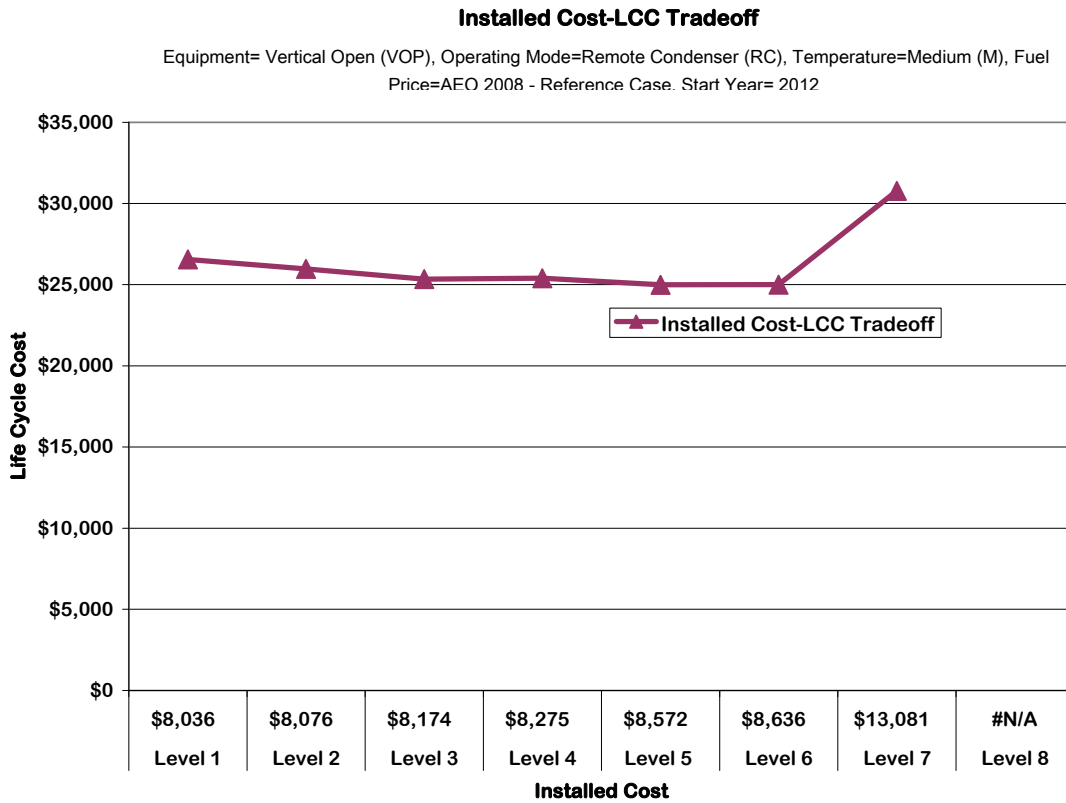
Figure 8.4.1 shows how, on an average basis, the total installed costs and LCC vary with efficiency level for a given building type. Similar figures for other equipment classes are provided in appendix G.

DOE separated the figures for total installed cost into equipment price and installation cost. It separated the figures for annual operating cost into annual electricity, repair, and maintenance costs. It separated the figures for LCC into total installed cost and lifetime operating cost. Although these figures show only mean or average values rather than distributions of LCC results, they demonstrate how the various inputs impact LCC. In view of the total installed cost results for both equipment classes, the equipment price is the largest contributor to increased total cost since the installation cost remains relatively constant across efficiencies.

Annual electricity cost is the largest contributor to the overall operating cost at any efficiency level. As efficiency is increased, electricity cost decreases.

The LCC results reveal that as efficiency is increased, the lifetime operating cost has more of an impact on the LCC than the total installed cost. In other words, the decrease in lifetime operating costs offsets the increase in total installed cost that occurs with an increase in rated efficiency. As a result, the LCC at all efficiency levels is lower than that for the baseline level (Level 1).

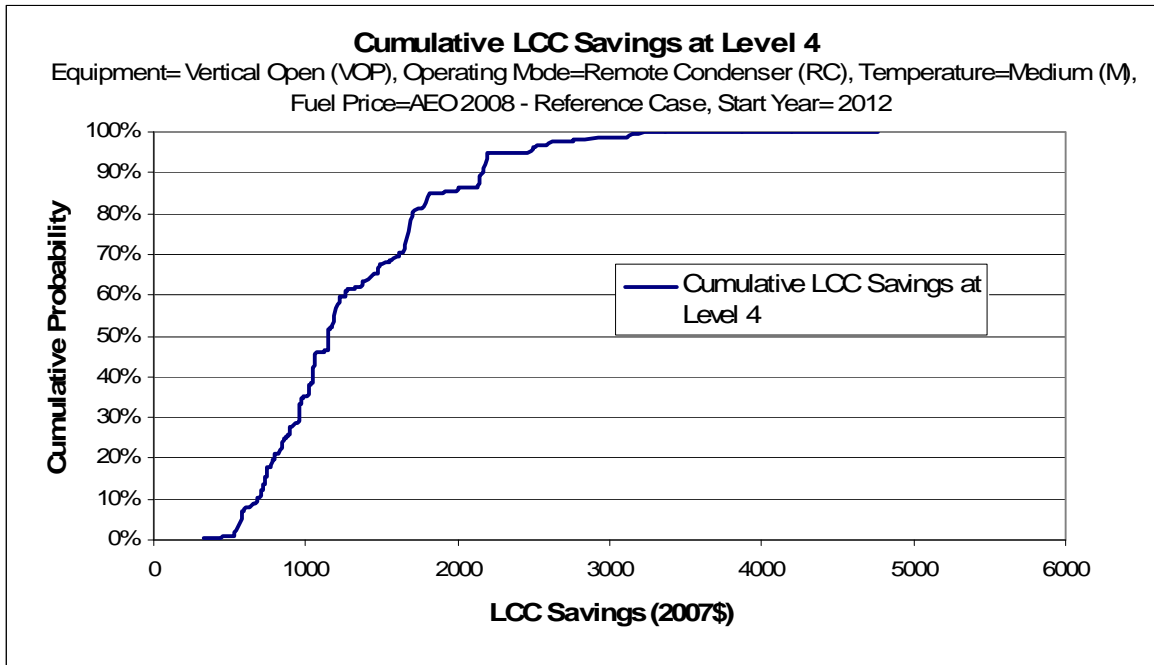
Again, the results shown in Figure 8.4.1 are based on average input values rather than input distributions and are depicted for only one building type. Thus, one can observe how the various inputs impact LCC and, in turn, how the resulting LCC changes with an increase in efficiency level in this example. Conclusions, however, should also take into account the distribution of LCC results discussed in section 8.4.1.2.



**Figure 8.4.1 Effect of the Change in Efficiency Level on Life-Cycle Cost for Vertical Open Display Case, Remote Condensing, Medium Temperature in Supermarkets (2007\$) at Average U.S. Conditions (Level 1 is the Baseline Level).**

**8.4.1.2 Differences in Life-Cycle Cost Between Baseline and Standard-Level Equipment**

DOE’s first step in developing LCC results was to establish the baseline LCC for each of the commercial refrigeration equipment classes. Unlike many recent DOE rulemakings, commercial refrigeration equipment has no pre-existing Federal standard, voluntary standard (e.g., ASHRAE), or other convenient reference standard available to serve as a baseline. As discussed in section 8.2.2.1, DOE’s baseline energy efficiency level for the ANOPR analysis is Level 1.



**Figure 8.4.2 Cumulative Chart of Life-Cycle Cost Savings for Vertical Open Display Case, Remote Condensing, Medium Temperature: Efficiency Level 4**

This section presents the differences in the LCC of standard level equipment relative to the baseline commercial refrigeration equipment. The LCC differences are depicted as a distribution of values. DOE presents the results in a cumulative chart showing the cumulative distribution of LCC differences along with the corresponding probability of occurrence for each given efficiency level. In each figure, DOE provides the mean LCC difference along with the percent of the population for which the LCC will decrease. In the case of commercial refrigeration equipment, the population is the number of CRE units in commercial buildings (grocery and convenience stores) that utilize commercial refrigeration equipment.

Figure 8.4.2 presents the LCC results for the case of efficiency Level 4 in the VOP.RC.M equipment class across all building types. Similar figures for other efficiency levels are found in appendix G for all equipment classes. In Figure 8.4.2, the 50-percent line shows the median change in LCC (a savings of \$1,152 in this example). Half of the purchasers of this commercial refrigeration equipment would save more than \$1,152, while half would save less than \$1,152. The “0” horizontal line is the minimum savings value, which in this example is \$332 savings due to the increased efficiency at efficiency level 4 compared to the baseline efficiency level (Level 1). The maximum LCC savings is \$3,873.

Appendix G contains the cumulative charts for all the efficiency levels considered for all commercial refrigeration equipment classes. These charts provide more complete information, but DOE provides a summary of the change in LCC from the baseline by percentile groupings (i.e., of the distribution of results) for each of the equipment classes in Table 8.4.1. Table 8.4.1 also shows the mean LCC savings and the percent of LCCs that are reduced for a standard set at each efficiency level.

**Table 8.4.1 Distribution of Life-Cycle Cost Savings from a Baseline Level (Level 1) by Efficiency Level for VOP.RC.M**

Efficiency Level	Decrease in LCC from Baseline (Level 1) Shown by Percentiles of the Distribution of Results (2007\$)												Mean Savings	Percent of Units with LCC Savings
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%			
Level 2	\$273	\$399	\$443	\$502	\$535	\$571	\$613	\$754	\$773	\$949	\$1,558	\$630	100%	
Level 3	\$540	\$824	\$923	\$1,055	\$1,129	\$1,212	\$1,306	\$1,619	\$1,665	\$2,062	\$3,437	\$1,344	100%	
Level 4	\$332	\$679	\$799	\$960	\$1,048	\$1,152	\$1,258	\$1,611	\$1,704	\$2,164	\$3,873	\$1,308	100%	
Level 5	\$410	\$897	\$1,068	\$1,294	\$1,414	\$1,566	\$1,713	\$2,232	\$2,343	\$3,013	\$5,419	\$1,788	100%	
Level 6	\$376	\$874	\$1,047	\$1,278	\$1,400	\$1,557	\$1,705	\$2,238	\$2,349	\$3,035	\$5,493	\$1,783	100%	
Level 7	-\$5,720	-\$5,112	-\$4,908	-\$4,603	-\$4,472	-\$4,207	-\$4,103	-\$3,328	-\$3,210	-\$2,264	\$1,227	-\$3,959	0%	
Level 8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	

As an example of how to interpret the information in Table 8.4.1, here is a review of the results for the VOP.RC.M equipment class. The Level 4 efficiency level in Table 8.4.1 (row 3) shows that the change in LCC in the zero-percentile column is a minimum saving of \$332. This means that the 100 percent of the market are estimated to have LCC savings of \$332. For 90 percent of the cases studied (90<sup>th</sup> percentile), the change in LCC for Level 4 is a LCC reduction of \$2,164 or less compared with the base case. Consequently, 10 percent of the cases have LCC savings of greater than \$2,164. The largest reduction in LCC for Level 4 is \$3,873 at the 100<sup>th</sup> percentile. The mean change in LCC is a net savings of \$1,308. The last column shows that 100 percent of the sample has LCC savings (i.e., reductions in LCC greater than zero) when compared to the baseline efficiency level.

Table 8.4.2 provides the national average life cycle cost savings calculated for each efficiency level when compared to the baseline (Level 1) for all product categories. Review of Table 8.4.2 shows that every efficiency level analyzed generated national average life cycle cost savings compared with the baseline.

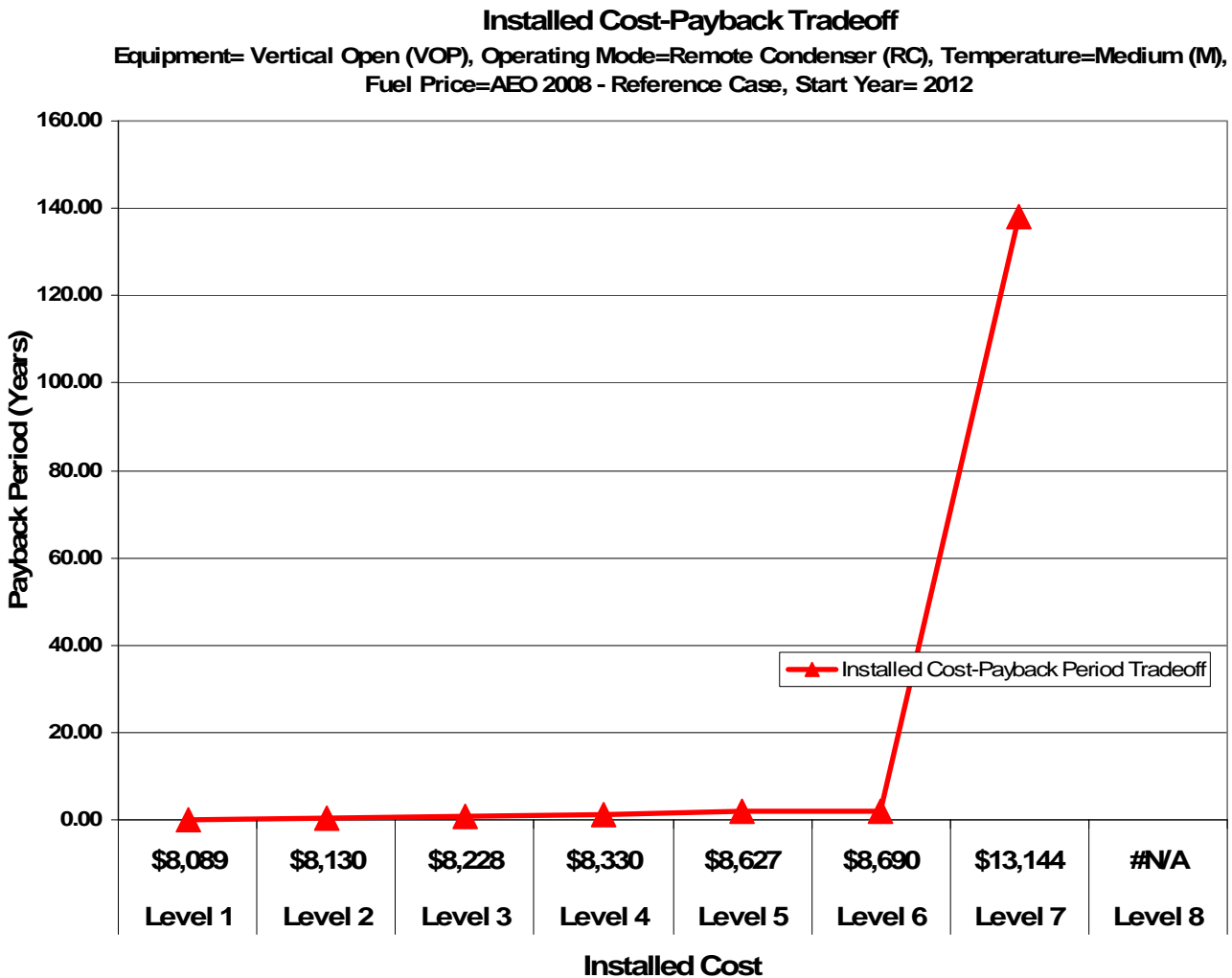
### 8.4.2 Payback Period Results

This section presents PBP results for each of the higher efficiency levels defined in section 8.2.2.2. The results presented here are based on annual operating costs calculated from state average commercial electricity prices. Section 8.2 describes the tariff-based electricity price inputs as well as all other PBP inputs.

Similar to LCC, the analysis provides an estimate of the simple payback period at different ranges of energy prices, sales taxes, and installation costs that prevail across the country for each efficiency level and each building (store) type. Figure 8.4.3 shows the effect on payback period as the efficiency level changes from Level 1 (the baseline), for VOP.RC.M equipment class in supermarkets at U.S. national average energy prices, sales taxes, and installation costs.

**Table 8.4.2 Average Life-Cycle Cost Savings from Baseline Level (Level 1) by Efficiency Level and Equipment Class**

Equipment Class	National Average LCC Savings (2007\$)							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	0	630	1344	1308	1788	1783	-3959	NA
VOP.RC.L	0	1625	3501	4500	4487	4610	3938	NA
VOP.SC.M	0	576	842	1143	1209	1549	1505	-451
VCT.RC.M	0	320	657	1673	2372	2375	2339	NA
VCT.RC.L	0	364	762	4137	5370	5450	5419	NA
VCT.SC.I	0	967	1910	2941	4893	5223	5234	5217
VCS.SC.I	0	360	704	1096	1321	1704	1740	1757
SVO.RC.M	0	430	907	896	1274	1251	-2974	NA
SVO.SC.M	0	457	583	824	853	1136	1087	-355
SOC.RC.M	0	405	851	851	945	-1184	-1217	-1458
HZO.RC.M	0	419	887	1063	1040	NA	NA	NA
HZO.RC.L	0	318	668	1047	1102	NA	NA	NA
HZO.SC.M	0	264	344	459	615	846	861	826
HZO.SC.L	0	583	670	1191	1215	1771	1784	1761
HCT.SC.I	0	159	211	775	797	785	NA	NA
	Percent of Units with Positive LCC Savings							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	0%	100%	100%	100%	100%	100%	0%	NA
VOP.RC.L	0%	100%	100%	100%	100%	100%	100%	NA
VOP.SC.M	0%	100%	100%	100%	100%	100%	100%	30%
VCT.RC.M	0%	100%	100%	100%	100%	100%	100%	NA
VCT.RC.L	0%	100%	100%	100%	100%	100%	100%	NA
VCT.SC.I	0%	100%	100%	100%	100%	100%	100%	100%
VCS.SC.I	0%	100%	100%	100%	100%	100%	100%	100%
SVO.RC.M	0%	100%	100%	100%	100%	100%	0%	NA
SVO.SC.M	0%	100%	100%	100%	100%	100%	100%	30%
SOC.RC.M	0%	100%	100%	100%	100%	13%	13%	5%
HZO.RC.M	0%	100%	100%	100%	100%	NA	NA	NA
HZO.RC.L	0%	100%	100%	100%	100%	NA	NA	NA
HZO.SC.M	0%	100%	100%	100%	100%	100%	100%	100%
HZO.SC.L	0%	100%	100%	100%	100%	100%	100%	100%
HCT.SC.I	0%	100%	100%	100%	100%	100%	NA	NA

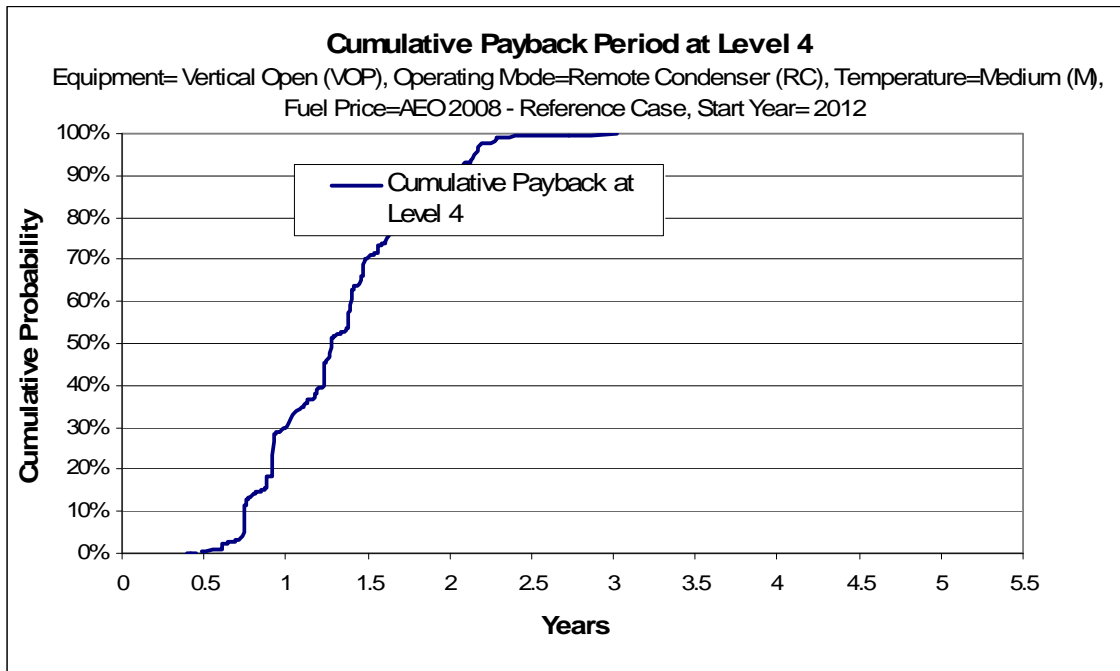


**Figure 8.4.3 Effect of the Change in Efficiency Level on Payback Period for Vertical Open Display Case, Remote Condensing, Medium Temperature, in Supermarkets at Average U.S. Conditions (Level 1 is the Baseline Level).**

Similar to the LCC differences, DOE depicted PBP results as a distribution of values. Thus, it presents the results as a cumulative probability chart showing the distribution of PBPs with the corresponding cumulative probability of occurrence. Each chart provides the mean PBP.

Figure 8.4.4 is an example of a cumulative probability chart showing the distribution of payback periods for each of the higher efficiency levels analyzed for the VOP.RC.M equipment class. Appendix G contains the frequency charts for all the efficiency levels considered for all commercial refrigeration equipment in this analysis. In Figure 8.4.4, the y-axis shows cumulative percent of all VOP.RC.M units (“Probability” at left y-axis). The x-axis is the PBP of a higher efficiency level (in this example, Level 4) relative to the baseline efficiency level

(Level 1). In Figure 8.4.4, a Level 4 efficiency level provides commercial refrigeration units in this equipment class with a median PBP of 1.4 years, a mean payback period of 1.5 years, and a payback period range from just greater than 0.4 years to approximately 3.3 years depending on the placement of the unit. (Note that these cannot be read with precision from the chart; rather, the analysis output data provides these values in a statistical summary.)



**Figure 8.4.4 Cumulative Chart of Payback Period for Vertical Open Display Case, Remote Condensing, Medium Temperature: Efficiency Level 4**

Table 8.4.3 summarizes the PBP results for each of the VOP.RC.M equipment class efficiency levels. Results are summarized for PBP by percentile groupings (i.e., percentile of the distribution of results). The table also shows the mean PBP for each efficiency level.

**Table 8.4.3 Summary of Payback Period Results for Vertical Open Display Case, Remote Condensing, Medium Temperature, Efficiency Level 4**

Efficiency Level	Payback Period in Years Shown by Percentiles of the Distribution of Results											Mean
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	
Level 2	0.2	0.3	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.9	0.5
Level 3	0.3	0.5	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.1	1.5	0.8
Level 4	0.4	0.7	0.9	1.0	1.2	1.3	1.4	1.5	1.7	1.9	3.0	1.3
Level 5	0.6	1.1	1.4	1.5	1.8	1.9	2.1	2.2	2.5	2.8	4.1	2.0
Level 6	0.7	1.2	1.5	1.7	2.0	2.1	2.3	2.4	2.7	3.0	4.5	2.1
Level 7	5.5	13.1	19.1	23.8	36.3	41.2	53.5	71.8	>100	>100	>100	>100
Level 8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 8.4.4 provides the national average payback calculated for each efficiency level when compared to the baseline (Level 1) for all equipment classes. Table 8.4.4 also shows the percentage of units reporting payback periods of less than 3 years.

**Table 8.4.4 National Average Payback Periods by Efficiency Level and Equipment Class**

Equipment Type	National Average Payback Period (Years)							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	NA	0.5	0.8	1.3	2.0	2.1	138.1	NA
VOP.RC.L	NA	0.5	0.7	1.1	1.1	1.2	2.8	NA
VOP.SC.M	NA	0.4	0.8	1.2	1.6	2.4	2.7	11.2
VCT.RC.M	NA	0.8	1.3	2.6	3.8	3.8	3.9	NA
VCT.RC.L	NA	0.7	1.1	2.4	2.5	2.5	2.6	NA
VCT.SC.I	NA	0.3	0.6	1.0	1.5	1.6	1.6	1.7
VCS.SC.I	NA	0.3	0.4	0.5	0.6	1.0	1.2	1.3
SVO.RC.M	NA	0.5	0.8	1.3	1.9	2.2	196.8	NA
SVO.SC.M	NA	0.4	0.6	1.1	1.4	2.3	2.7	11.5
SOC.RC.M	NA	0.5	0.8	1.4	1.7	19.2	19.0	19.4
HZO.RC.M	NA	0.5	0.8	1.2	1.6	NA	NA	NA
HZO.RC.L	NA	0.7	1.0	1.4	1.6	NA	NA	NA
HZO.SC.M	NA	0.3	0.4	0.7	1.0	1.8	1.8	2.3
HZO.SC.L	NA	0.3	0.3	0.8	0.8	1.4	1.5	1.7
HCT.SC.I	NA	0.5	0.6	1.4	1.5	1.9	NA	NA
	Percent of Units with Payback Period Less than 3 Years							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	0%	100%	100%	100%	93%	90%	NA	NA
VOP.RC.L	0%	100%	100%	100%	100%	100%	63%	NA
VOP.SC.M	0%	100%	100%	100%	100%	77%	71%	0%
VCT.RC.M	0%	100%	100%	71%	29%	29%	19%	NA
VCT.RC.L	0%	100%	100%	83%	76%	74%	71%	NA
VCT.SC.I	0%	100%	100%	100%	100%	100%	100%	100%
VCS.SC.I	0%	100%	100%	100%	100%	100%	100%	100%
SVO.RC.M	0%	100%	100%	100%	94%	87%	NA	NA
SVO.SC.M	0%	100%	100%	100%	100%	83%	71%	0%
SOC.RC.M	0%	100%	100%	100%	99%	NA	NA	NA
HZO.RC.M	0%	100%	100%	100%	100%	NA	NA	NA
HZO.RC.L	0%	100%	100%	100%	100%	NA	NA	NA
HZO.SC.M	0%	100%	100%	100%	100%	100%	99%	86%
HZO.SC.L	0%	100%	100%	100%	100%	100%	100%	100%
HCT.SC.I	0%	100%	100%	100%	100%	99%	NA	NA

**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, standard-compliant equipment, and compared this cost to the value of the energy saved during the first year of operation of the equipment as determined by ARI 1200-2006. DOE interprets that the increased cost of purchasing standard-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 this payback period is less than three years, the rebuttable presumption is satisfied; when this payback period

is equal to or more than three years, the rebuttable presumption is not satisfied. Note that this payback period calculation does not include other components to the annual operating cost of the equipment (i.e., maintenance costs and repair costs). The rebuttable presumption payback periods calculated can thus be different from the payback periods calculated in section 8.4.2.

DOE calculated the rebuttable presumption payback periods for the distribution of installed costs and energy prices discussed in sections 8.4.1 and 8.4.2 representative of the same four types of businesses and all 50 States. The baseline efficiency level for the rebuttable presumption calculation is the Level 1 baseline efficiency. The rebuttable presumption payback period was calculated for each higher efficiency level within each equipment class.

Table 8.4.5 shows the nationally-averaged rebuttable presumption payback periods calculated for all equipment classes and efficiency levels. The highest efficiency level with a rebuttable presumption payback period of less than three years is also shown in Table 8.4.5 for each equipment class.

**Table 8.4.5 Rebuttable Presumption Payback Periods by Efficiency Level and Equipment Class**

Equipment Class	Rebuttable Presumption Payback Period (Years)							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	NA	0.5	0.7	1.0	1.6	1.8	11.1	NA
VOP.RC.L	NA	0.4	0.7	1.0	1.1	1.1	2.4	NA
VOP.SC.M	NA	0.4	0.7	1.2	1.4	2.2	2.4	6.9
VCT.RC.M	NA	0.7	1.1	2.7	3.7	3.8	3.9	NA
VCT.RC.L	NA	0.7	1.0	2.3	2.5	2.5	2.6	NA
VCT.SC.I	NA	0.3	0.5	1.0	1.5	1.6	1.6	1.7
VCS.SC.I	NA	0.3	0.4	0.5	0.6	0.9	1.2	1.3
SVO.RC.M	NA	0.5	0.7	1.0	1.6	1.8	11.5	NA
SVO.SC.M	NA	0.4	0.6	1.1	1.3	2.2	2.5	7.0
SOC.RC.M	NA	0.5	0.8	1.1	1.4	7.8	7.9	8.6
HZO.RC.M	NA	0.5	0.7	1.2	1.5	NA	NA	NA
HZO.RC.L	NA	0.6	0.9	1.3	1.6	NA	NA	NA
HZO.SC.M	NA	0.3	0.4	0.7	1.0	1.7	1.8	2.2
HZO.SC.L	NA	0.3	0.3	0.7	0.8	1.4	1.5	1.7
HCT.SC.I	NA	0.5	0.6	1.3	1.4	1.9	NA	NA

## 8.5 LCC SENSITIVITY STUDIES

Sensitivity analyses were conducted to evaluate how the LCC and PBP results change with changes in fuel escalation rate and baseline efficiency level. The results of these are discussed in sections 8.5.1 and 8.5.2

### 8.5.1 Sensitivity to Fuel Escalation Rate

Sensitivity to fuel escalation rate was examined using the escalation rates provided in the *AEO 2008* high price and low price scenarios. Table 8.5.1 and

Table 8.5.2 examine the national average LCC savings for the *AEO 2008* low energy price scenario and *AEO 2008* high energy price scenarios respectively. For the high price scenario, while the average LCC savings is increased for most efficiency levels above the baseline when compared with the reference case, there are no changes in the level showing the highest LCC savings when compared with the results using *AEO 2008* reference case. For the low price scenario, the average LCC savings is reduced for all efficiency levels above the baseline when compared with the reference case (see Table 8.4.2). However, there are no changes in the level showing the highest LCC savings when compared with the results using *AEO 2008* reference case

Payback period is calculated based on first year energy savings and thus is insensitive to fuel escalation rate scenarios.

**Table 8.5.1 Average Life-Cycle Cost Savings from a Baseline Level (Level 1) by Efficiency Level and Equipment Class – EIA Low Price Scenario**

Equipment Class	National Average LCC Savings (2007\$)							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	0	605	1287	1238	1689	1682	-4096	N/A
VOP.RC.L	0	1560	3353	4302	4284	4400	3694	N/A
VOP.SC.M	0	554	807	1093	1148	1462	1418	-551
VCT.RC.M	0	307	626	1585	2211	2212	2174	N/A
VCT.RC.L	0	349	727	3920	5087	5162	5127	N/A
VCT.SC.I	0	930	1834	2822	4677	4987	4997	4976
VCS.SC.I	0	346	677	1052	1268	1632	1664	1679
SVO.RC.M	0	412	868	847	1204	1180	-3070	N/A
SVO.SC.M	0	440	559	788	812	1074	1025	-426
SOC.RC.M	0	388	814	804	892	-1286	-1319	-1565
HZO.RC.M	0	402	849	1015	991	N/A	N/A	N/A
HZO.RC.L	0	305	638	999	1049	N/A	N/A	N/A
HZO.SC.M	0	254	330	440	588	806	819	783
HZO.SC.L	0	561	644	1142	1165	1691	1703	1678
HCT.SC.I	0	153	202	741	761	747	N/A	N/A
	Percent of Units with Positive LCC Savings							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	0%	100%	100%	100%	100%	100%	0%	N/A
VOP.RC.L	0%	100%	100%	100%	100%	100%	100%	N/A
VOP.SC.M	0%	100%	100%	100%	100%	100%	100%	20%
VCT.RC.M	0%	100%	100%	100%	100%	100%	100%	N/A
VCT.RC.L	0%	100%	100%	100%	100%	100%	100%	N/A
VCT.SC.I	0%	100%	100%	100%	100%	100%	100%	100%
VCS.SC.I	0%	100%	100%	100%	100%	100%	100%	100%
SVO.RC.M	0%	100%	100%	100%	100%	100%	0%	N/A
SVO.SC.M	0%	100%	100%	100%	100%	100%	100%	19%
SOC.RC.M	0%	100%	100%	100%	100%	5%	5%	5%
HZO.RC.M	0%	100%	100%	100%	100%	N/A	N/A	N/A
HZO.RC.L	0%	100%	100%	100%	100%	N/A	N/A	N/A
HZO.SC.M	0%	100%	100%	100%	100%	100%	100%	100%
HZO.SC.L	0%	100%	100%	100%	100%	100%	100%	100%
HCT.SC.I	0%	100%	100%	100%	100%	100%	N/A	N/A

**Table 8.5.2 Average Life-Cycle Cost Savings from a Baseline Level (Level 1) by Efficiency Level and Equipment Class – EIA High Price Scenario**

Equipment Class	National Average LCC Savings (2007\$)							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	0	659	1409	1386	1899	1897	-3805	N/A
VOP.RC.L	0	1698	3665	4720	4714	4844	4212	N/A
VOP.SC.M	0	601	882	1200	1276	1645	1603	-339
VCT.RC.M	0	336	691	1773	2552	2558	2524	N/A
VCT.RC.L	0	382	801	4380	5687	5773	5746	N/A
VCT.SC.I	0	1009	1996	3074	5134	5488	5500	5486
VCS.SC.I	0	375	735	1145	1381	1785	1825	1844
SVO.RC.M	0	449	950	950	1353	1331	-2865	N/A
SVO.SC.M	0	477	609	864	899	1205	1157	-275
SOC.RC.M	0	423	892	903	1004	-1071	-1102	-1338
HZO.RC.M	0	438	929	1116	1096	N/A	N/A	N/A
HZO.RC.L	0	333	701	1101	1161	N/A	N/A	N/A
HZO.SC.M	0	275	359	481	644	891	907	874
HZO.SC.L	0	608	699	1246	1271	1861	1875	1854
HCT.SC.I	0	166	221	814	838	828	N/A	N/A
	Percent of Units with Positive LCC Savings							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
VOP.RC.M	0%	100%	100%	100%	100%	100%	0%	N/A
VOP.RC.L	0%	100%	100%	100%	100%	100%	100%	N/A
VOP.SC.M	0%	100%	100%	100%	100%	100%	100%	31%
VCT.RC.M	0%	100%	100%	100%	100%	100%	100%	N/A
VCT.RC.L	0%	100%	100%	100%	100%	100%	100%	N/A
VCT.SC.I	0%	100%	100%	100%	100%	100%	100%	100%
VCS.SC.I	0%	100%	100%	100%	100%	100%	100%	100%
SVO.RC.M	0%	100%	100%	100%	100%	100%	0%	N/A
SVO.SC.M	0%	100%	100%	100%	100%	100%	100%	30%
SOC.RC.M	0%	100%	100%	100%	100%	14%	14%	13%
HZO.RC.M	0%	100%	100%	100%	100%	N/A	N/A	N/A
HZO.RC.L	0%	100%	100%	100%	100%	N/A	N/A	N/A
HZO.SC.M	0%	100%	100%	100%	100%	100%	100%	100%
HZO.SC.L	0%	100%	100%	100%	100%	100%	100%	100%
HCT.SC.I	0%	100%	100%	100%	100%	100%	N/A	N/A

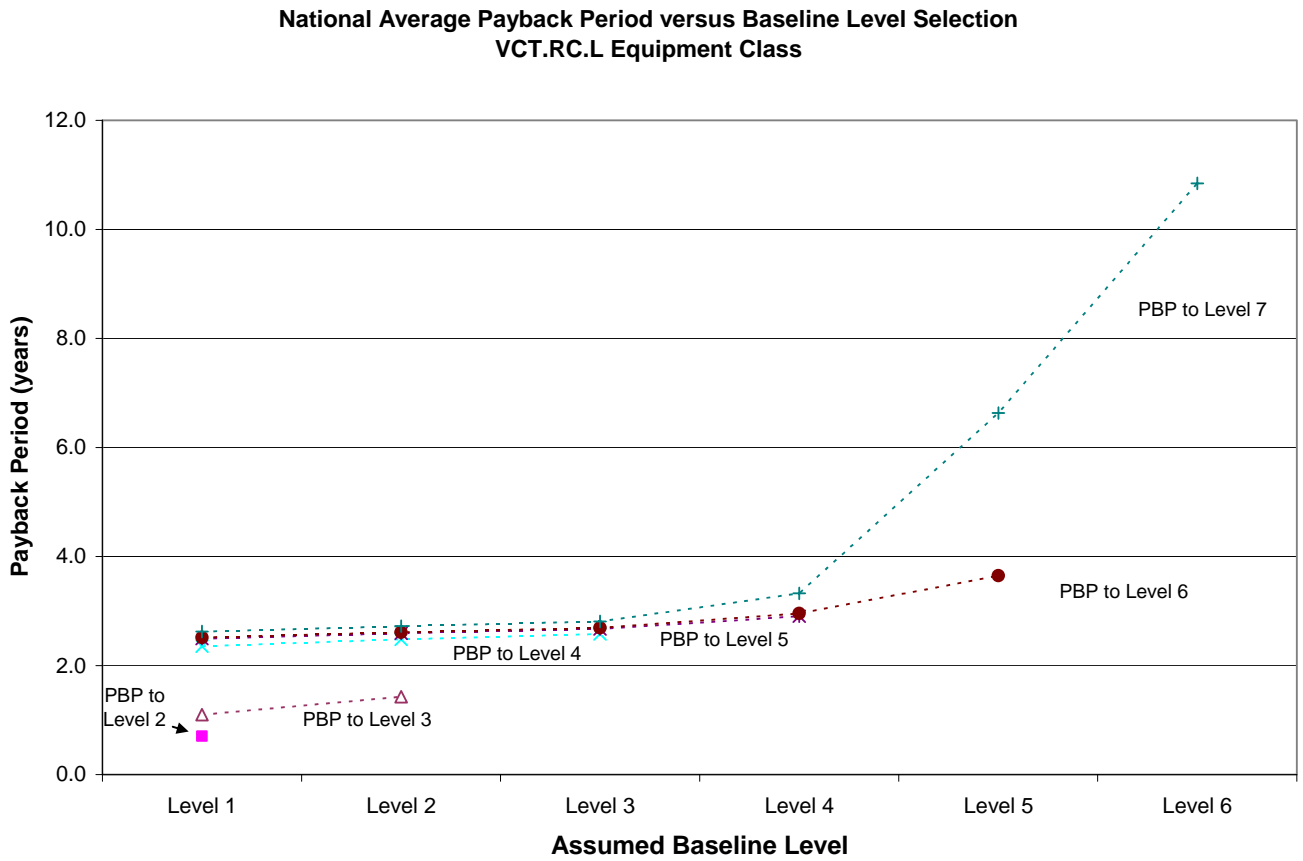
### 8.5.2 Sensitivity to Baseline Efficiency Level

Sensitivity to the baseline efficiency level was carried out using the LCC analysis spreadsheet to calculate LCC Savings and Payback Period for each efficiency level using alternative efficiency levels (e.g., Level 2) selected as the baseline level. The analysis was first carried out for a single equipment class (VCT.RC.L) and summing over all business types and fuel costs. The results of this analysis, assuming baseline levels at Level 1, Level 2, Level 3, and Level 4 are shown in Table 8.5.3. For this product and business type, it is clear that as the assumed baseline level moves from Level 1 to Level 4, the average LCC savings calculated for each level higher than the baseline are reduced, and the average payback period calculated for each higher efficiency level increases. The maximum life cycle cost savings is achieved at Level 6. Payback periods to reach a given efficiency level (e.g., Level 7) increase as higher baseline levels are assumed. For Level 7, the PBP was 2.8years calculated with a Level 1 baseline. PBP is increased to 3.3 years for a Level 4 baseline.

**Table 8.5.3 Sensitivity of Average Life-Cycle Cost Savings and Payback Period to Selection of Baseline Efficiency Level --VCT.RC.L Equipment Class**

Baseline Level	Average LCC Savings (2007\$)							
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7	Level 8
Level 1	0	364	762	4137	5370	5450	5419	N/A
Level 2	N/A	0	397	3773	5006	5085	5055	N/A
Level 3	N/A	N/A	0	3375	4608	4688	4657	N/A
Level 4	N/A	N/A	N/A	0	1233	1313	1282	N/A
	Average Payback Period (Years)							
Level 1	N/A	0.7	1.1	2.4	2.5	2.5	2.6	N/A
Level 2	N/A	0.0	1.4	2.5	2.6	2.6	2.7	N/A
Level 3	N/A	0.0	0.0	2.6	2.7	2.7	2.8	N/A
Level 4	N/A	0.0	0.0	0.0	2.9	3.0	3.3	N/A

Table 8.5.3 results are for one equipment class and one business type using national average electricity rates. The behavior of other equipment classes is qualitatively similar, i.e., the LCC savings is reduced and the payback period is increased when higher efficiency levels are assumed as the baseline level. However, the degree of change in LCC or payback depends on the relative shape of the cost-efficiency curves. To examine the impact of baseline level on a national basis, the LCC spreadsheet was exercised for all business types and equipment classes and state-by-state electricity prices. The resulting LCC savings and payback periods were aggregated to national average values. These results are found in appendix G. Figure 8.5.1 illustrates the impact on PBP for VCT.RC.L. The data points along each line of the chart indicate the calculated PBP for the efficiency level indicated for the line assuming the baseline level shown on the horizontal axis. The variation in the height of points along a given line (each line representing a specific target efficiency level) indicates the sensitivity of that level to the choice of baseline. Figure 8.5.1 shows the PBP for the VCT.RC.L equipment class is sensitive to the choice of baseline level, and that the overall PBP to reach Level 5 varies by approximately 1.3 years depending on the baseline level assumed for Levels 1 – 4. PBP to reach Level 6 or Level 7 vary significantly depending on the choice of baseline level.



**Figure 8.5.1 Sensitivity of Payback Period to Baseline Efficiency Level – VCT.RC.L Equipment Class**

## 8.6 DETAILED RESULTS

DOE presents more detailed results and supporting data for the LCC analysis in Appendix G.

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