

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	8-3
8.2	LIFE-CYCLE COST INPUTS	8-7
8.2.1	Definition	8-7
8.2.2	Total Installed-Cost Inputs.....	8-8
8.2.2.1	Baseline Energy Consumption and Manufacturer Selling Price.....	8-8
8.2.2.2	Candidate Standard-Level Energy Consumption and Manufacturer Selling Price Increases	8-10
8.2.2.3	Overall Markup.....	8-12
8.2.2.4	Installation Cost	8-12
8.2.2.5	Weighted Average Total Installed Cost.....	8-13
8.2.3	Operating-Cost Inputs.....	8-16
8.2.3.1	Electricity Price Analysis.....	8-16
8.2.3.2	Electricity Price Trend	8-18
8.2.3.3	Repair Cost.....	8-19
8.2.3.4	Maintenance Cost.....	8-19
8.2.3.5	Lifetime.....	8-20
8.2.3.6	Discount Rate.....	8-20
8.2.3.7	Compliance Date of Standard	8-23
8.3	PAYBACK PERIOD INPUTS	8-23
8.3.1	Definition	8-23
8.3.2	Inputs.....	8-24
8.4	LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS	8-24
8.4.1	Life-Cycle Cost Results	8-24
8.4.2	Payback Period Results.....	8-28
8.4.3	Rebuttable Presumption Payback Period	8-31
8.5	DETAILED RESULTS	8-32
	REFERENCES	8-34

LIST OF TABLES

Table 8.1.1 Summary Information of Inputs for the Determination of Life-Cycle Cost and Payback Period.....	8-7
Table 8.2.1 Inputs for Total Installed Costs.....	8-8
Table 8.2.2 Equipment Classes Evaluated for the Automatic Commercial Ice-Making Equipment Standard Life-Cycle Cost and Payback Period Analysis.....	8-9
Table 8.2.3 Baseline Energy Consumption Levels and Estimated MSP Values for the Representative Automatic Commercial Ice-Making Equipment Units of All 21 Primary Equipment Classes.....	8-10
Table 8.2.4 Baseline Manufacturer Selling Prices for Representative Automatic Commercial Ice-Making Equipment Units of the 21 Primary Equipment Classes and Incremental Manufacturer Selling Prices for All Efficiency Levels Within the Equipment Classes.....	8-11
Table 8.2.5 Energy Consumption Values for Representative Automatic Commercial Ice-Making Equipment Units of the 21 Primary Equipment Classes and All Efficiency Levels Within the Equipment Classes.....	8-12
Table 8.2.6 Installation Cost Indices (National Value = 100.0).....	8-13
Table 8.2.7 Costs and Markups for Determination of Weighted Average Total Installed Costs (IMH-A-Small-B).....	8-14
Table 8.2.8 Weighted Average Equipment Price, Installation Cost, and Total Installed Costs for IMH-A-Small-B at U.S. Average Conditions (2010\$)*.....	8-15
Table 8.2.9 Inputs Used to Determine Operating Costs.....	8-16
Table 8.2.10 Commercial Electricity Prices by State (2010 cents/kWh).....	8-17
Table 8.2.11 Derived National Average Commercial Electricity Prices and Ratios by Business Type.....	8-18
Table 8.2.12 Annualized Maintenance Costs by Equipment Class for Each Efficiency Level.....	8-20
Table 8.2.13 Derivation of Typical Discount Rates by Building Type*.....	8-23
Table 8.4.1 LCC Savings Distribution Results for Equipment Class IMH-A-Small-B.....	8-26
Table 8.4.2 Mean LCC Savings for All Equipment Classes and Efficiency Levels.....	8-27
Table 8.4.3 Median LCC Savings for All Equipment Classes and Efficiency Levels.....	8-28
Table 8.4.4 Payback Period Distribution Results for IMH-A-Small-B.....	8-29
Table 8.4.5 Mean Payback Period for All Equipment Classes and Efficiency Levels.....	8-30
Table 8.4.6 Median Payback Period for All Equipment Classes and Efficiency Levels.....	8-31
Table 8.4.7 Rebuttable Presumption Payback Periods by Efficiency Level and Equipment Class.....	8-32
Table 8.5.1 Summary of Results of LCC and PBP Analysis for IMH-A-Small-B Equipment Class.....	8-33

LIST OF FIGURES

Figure 8.1.1 Flow Diagram of Inputs for the Determination of Life-Cycle Cost and Payback
Period 8-6

Figure 8.2.1 Electricity Price Trends for Commercial Rates to 2045..... 8-19

Figure 8.4.1 LCC and Installed Cost Variation over Efficiency Levels for IMH-A-Small-B
Equipment Class 8-25

Figure 8.4.2 Ranges of LCC Savings for All the Efficiency Levels for the Equipment Class IMH-
A-Small-B 8-26

Figure 8.4.3 Mean Payback Period for All Efficiency Levels for the Equipment Class IMH-A-
Small-B 8-29

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 of possible energy conservation standards developed for automatic commercial ice makers on individual commercial customers, henceforth referred to as *customers*. The effect of standards on customers includes changes in operating costs (usually decreased) and changes in purchase costs (usually increased). This chapter describes two metrics used to determine the effect of standards on customers:

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

An efficiency improvement in automatic commercial ice makers that is financially attractive to a customer will typically have a low PBP and a low LCC associated with it.

The remainder of this section outlines the general approach and provides an overview of the inputs to the LCC and PBP analysis of automatic commercial ice makers. Inputs to the LCC and PBP analysis are discussed in detail in sections 8.2 and 8.3. Results for the LCC and PBP analysis are presented in sections 8.4 and 8.5.

DOE performed the calculations discussed in this chapter using a series of Microsoft Excel spreadsheets, which are available at (www1.eere.energy.gov/buildings/appliance_standards/commercial/automatic_ice_making_equipment.html). Appendix 8A includes instructions for using the spreadsheets. Appendix 8B presents the detailed results.

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

This section summarizes DOE's approach to the LCC and PBP analysis for automatic commercial ice makers.

As part of the engineering analysis (chapter 5 of the preliminary technical support document (preliminary TSD)), DOE explored various efficiency levels based on increasing efficiency (decreased energy consumption) and, typically, increasing manufacturer selling price (MSP) values. For the LCC and PBP analysis, DOE choose a maximum of seven levels, referred to herein as *efficiency levels*. DOE treats the efficiency levels as *candidate standard levels*, as each higher efficiency level represents a potential new standard level.

^a Water costs, as used in this chapter, are the total of water and wastewater costs. Wastewater utilities tend to not meter customer wastewater flows, and base billings on water commodity billings. For this reason, water usage is used as the basis for both water and wastewater costs, and the two are aggregated in the LCC and PBP analysis.

The first efficiency level (Level 1) in each equipment class is the least efficient and the least expensive equipment in that equipment class. The higher efficiency levels (Level 2 and up) have a progressive increase in efficiency and equipment cost from Level 1. The highest efficiency level in each equipment class corresponds to the maximum efficiency level obtainable with non-proprietary technology and without increasing the footprint of the equipment (see preliminary TSD chapter 5 for details).

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

Operating costs for automatic commercial ice makers are the sum of maintenance costs, repair costs, energy costs, and water costs. Customers incur these costs over the life of the equipment. To facilitate cost comparisons, DOE discounted operating costs to the discount year (2016, which is the effective date of the standards that will be established as part of this rulemaking). The sum of the installed cost and the operating costs, discounted to reflect the present value, is termed the life-cycle cost or LCC.

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

DOE obtained the PBP of higher efficiency equipment by dividing the increase in the installed cost by the decrease in annual operating cost, and compared each to the value of these parameters for the baseline unit. For this calculation, DOE used the sum of the first year operating cost changes as the estimate of the annual decrease in operating cost, noting that some of the repair and maintenance costs used herein are annualized estimates of costs. DOE calculated a PBP for each efficiency level of each equipment class.

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

DOE estimated many inputs for the LCC and PBP analysis from the best available data, and in some cases DOE used inputs that are generally accepted values within the automatic commercial ice maker industry. In general, there is uncertainty associated with most of the inputs as it is often difficult to obtain a single representative value for a given input. Therefore, DOE carried out the LCC and PBP analysis in the form of Monte Carlo simulations using ranges of

values and probability distributions for certain inputs that account for the uncertainties. DOE presents the results of the LCC and PBP analysis in the form of mean and median LCC savings; percentages of customers experiencing net savings, net cost, and no impact in LCC; and median PBP. For each equipment class, DOE carried out 10,000 Monte Carlo simulations using Microsoft Excel and Crystal Ball, a commercially available Excel add-in for performing Monte Carlo simulations.

DOE calculated LCC savings and PBP by comparing the installed costs and LCC values of a given standards scenario against those of the base-case scenario. The base-case scenario is the scenario in which customers purchase equipment in the absence of the proposed energy conservation standard. A standards-case scenario is a scenario in which customers purchase equipment after the hypothetical energy conservation standard goes into effect. The number of standards scenarios for an equipment class is equal to one less than the total number of efficiency levels in that equipment class because each efficiency level above Efficiency Level 1 represents a potential new standard. Usually, the market will offer equipment at various efficiencies. Therefore, for both the base-case and the standards-case scenarios in the LCC and PBP analysis, DOE calculates the market shares of the efficiency levels using a method described in preliminary TSD chapter 10.

Different types of buildings and industries face different energy prices, and apply different discount rates to purchase decisions. DOE analyzed variability and uncertainty by performing the LCC and PBP calculations for seven types of buildings: health care, lodging, foodservice, retail, education, food sales, and offices.

There is a general consensus among industry stakeholders that the typical equipment lifetime is approximately 7 to 10 years with an average of 8.5 years. There was no data or comment to suggest that lifetimes are unique to each equipment class. Therefore, DOE assumed a distribution of equipment lifetimes that is defined by Weibull survival functions, with an average value of 8.5 years (see section 8.2.3.5).

Another important factor influencing the LCC and PBP analysis is the location in which the automatic commercial ice maker is installed. Inputs that vary by location include installation costs, water and energy prices, and sales tax (plus the associated distribution chain markups). At the national level, DOE explicitly modeled variability in water price, electricity price, and markups using probability distributions based on the relative populations in all states.

Results of the LCC and PBP analysis are presented at the end of this chapter and in appendix 8B.

8.1.2 Overview of Life-Cycle Cost and Payback Period Inputs

DOE categorized inputs to the LCC and PBP analysis as: (1) inputs for establishing the total installed cost; and (2) inputs for calculating operating costs.

The primary inputs for establishing the total installed cost are:

- *Baseline manufacturer selling price:* The price charged by the manufacturer (when selling to either a wholesaler or customer) for equipment meeting the baseline efficiency level. The MSP includes a manufacturer's markup, which converts the MPC to MSP.
- *Price learning:* A method of adjusting the MSP over time to account for increasing cost efficiency in the production of automatic commercial ice-making equipment. DOE assumed that, with time and experience, the real cost of producing equipment will decrease marginally.
- *Candidate standard level manufacturer selling price increase:* The incremental change in MSP associated with producing equipment at a given higher efficiency level.
- *Markups and sales tax:* The distribution chain markups and sales tax used to convert the MSP to a customer purchase price. Preliminary TSD chapter 6 presents the methodology used to determine markups and sales taxes.
- *Installation cost:* The cost to the customer of installing the equipment, not including the equipment cost. DOE assumed the cost of installation as a one-time cost, and it is intended to represent the cost of labor, overhead, and other miscellaneous materials and parts.

The primary inputs for calculating the operating costs are:

- *Equipment energy consumption:* The energy consumed by an automatic commercial ice maker to produce 100 lb of ice, expressed in kilowatt-hours. DOE calculated this value as part of the engineering analysis for each candidate standard level in each equipment class.
- *Equipment water consumption:* The amount of condenser water (used to cool refrigerant in the open-loop condenser system) and potable water (used to form ice) to produce 100 lb of ice, expressed in gallons. DOE calculated this value as part of the engineering analysis (preliminary TSD chapter 7) for each candidate standard level in each equipment class.
- *Electricity price:* The price per kilowatt-hour, in cents or dollars, paid by each customer for electricity. DOE used average commercial electricity prices in each state, as determined from the Energy Information Administration (EIA) form 861 data for 2009. DOE adjusted 2009 to 2010 dollars using price deflators from EIA's *Annual Energy Outlook 2011*¹ (*AEO2011*). DOE then adjusted the average commercial prices to reflect the fact that the seven types of businesses analyzed pay electricity prices that are different from average commercial prices. Section 8.2.3.1 details the development of electricity prices and the data sources used.
- *Water and wastewater prices:* DOE combined the prices for water and wastewater in dollars per 1,000 gallons. DOE used price data from the 2010 American Water Works Water and Wastewater Survey.⁹ No data existed that disaggregated water prices for individual building types, so DOE varied prices by state only and not by building type within a state. Section 8.2.3.1 details the development of prices and the data sources used.

- *Electricity price trends*: DOE used the EIA's *AEO2011* to forecast electricity prices. For the results presented in this chapter, DOE used the regional prices from the *AEO2011* reference case to forecast future electricity prices.
- *Water and wastewater price trends*: DOE used the Consumer Price Index data for water related consumption (1970–2010) in developing a real growth rate for water and wastewater price forecasts.
- *Maintenance costs*: DOE calculated maintenance costs as an annual expense representing the estimated labor and materials costs associated with maintaining the operation of the equipment.
- *Repair costs*: DOE calculated the cost for repairs as an annual expense, representing the estimated labor and materials costs associated with repairing or replacing components that have failed.
- *Equipment lifetime*: The typical age at which the automatic commercial ice-making equipment is retired from service.
- *Discount rate*: The rate at which future costs are discounted to establish their present value.

Figure 8.1.1 depicts the relationships between the installed cost and operating cost inputs for the calculation of the LCC and PBP and how those costs vary with increasing efficiency. Table 8.1.1 summarizes the characteristics of the inputs to the LCC and PBP analysis, and lists the corresponding reference chapter in the preliminary TSD for details on the calculation of the inputs.

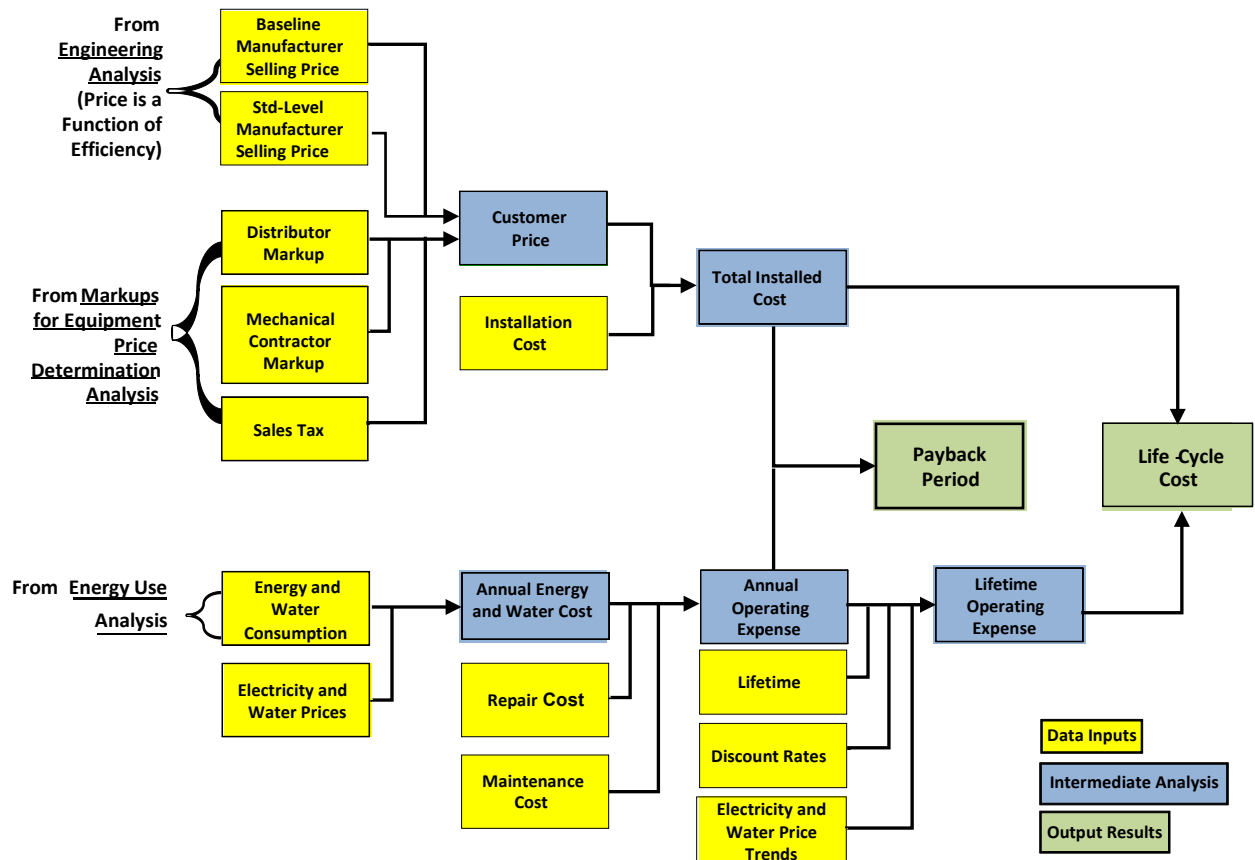


Figure 8.1.1 Flow Diagram of Inputs for the Determination of Life-Cycle Cost and Payback Period

Table 8.1.1 Summary Information of Inputs for the Determination of Life-Cycle Cost and Payback Period

Input	Description	TSD Chapter Reference
Total Installed Cost Primary Inputs		
Baseline MSP	Varies with equipment class.	Chapter 5
Candidate standard level MSP increases	Vary with equipment class and candidate standard level within an equipment class.	Chapter 5
Markups and sales tax	Markups vary with distribution channel and sales tax varies with location (state) where equipment is installed.	Chapter 6
Installation price	Vary with equipment class and state.	Chapter 8
Operating Cost Primary Inputs		
Equipment energy and water consumption	Varies with equipment class and candidate standard level within an equipment class.	Chapter 5
Electricity and water/wastewater prices	Vary with location, building type.	Chapter 8
Electricity and water/wastewater price trends	Vary with location (regional) and price scenario.	Chapter 8
Maintenance costs	Vary with equipment class and state.	Chapter 8
Repair costs	Vary with equipment class and state.	Chapter 8
Lifetime	Mean assumed to be 8.5 years for all equipment.	Chapters 3, 8
Discount rate	Varies with type of business.	Chapter 8

All of the inputs depicted in Figure 8.1.1 and summarized in Table 8.1.1 are discussed in sections 8.2 and 8.3.

8.2 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 equipment cost, installation cost, and operating costs (energy and water costs, maintenance costs, and repair costs). DOE discounted future operating costs to the time of purchase and summed costs over the lifetime of the equipment. Life-cycle cost is defined by the following equation:

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

Eq. 8.1

Where:

LCC = life-cycle cost (\$),

IC = total installed cost (\$),

N = lifetime of equipment (years)^b,

OC_t = operating cost (\$) of the equipment in year t ,

r = discount rate, and

t = year for which operating cost is being determined.

^b Though the average equipment life is 8.5 years, the model uses a range of years to calculate the equipment lifetime.

Because DOE gathered most of its data for the LCC analysis in 2010, DOE expressed all costs in 2010\$. Total installed cost, operating cost, lifetime, and discount rate are discussed in the following sections. In the LCC analysis, DOE assumed that the first year of equipment purchase is 2016, the presumed compliance date for standards set as a result of this rulemaking.

8.2.2 Total Installed-Cost Inputs

The following equation defines the total installed cost:

$$IC = EQP + INST$$

Eq. 8.2

Where:

EQP = customer purchase price for the equipment (\$), and
INST = installation cost or the customer price to install equipment (\$).

DOE based the equipment price on the distribution channel through which the customer purchases the equipment, as discussed in preliminary TSD chapter 6.

The remainder of this section provides information about the variables DOE used to calculate the total installed cost for automatic commercial ice-making equipment. Table 8.2.1 shows the inputs used to determine total installed cost.

Table 8.2.1 Inputs for Total Installed Costs

Baseline manufacturer selling price (\$)
Price learning coefficient
Candidate standard level manufacturer selling price increases (\$)
Wholesaler markup
Mechanical contractor markup
National account markup
Sales tax (\$)
Installation cost (\$)

8.2.2.1 Baseline Energy Consumption and Manufacturer Selling Price

The baseline MSP is the price manufacturers charge for equipment just meeting the existing minimum efficiency (or baseline) standards or base-case efficiency levels (for equipment classes with no standards). The MSP includes a markup that is applied to convert MPC to an MSP. DOE developed MSP values for the 21 primary equipment classes (see preliminary TSD chapter 5). Table 8.2.2 lists the 21 primary equipment classes that DOE evaluated during the preliminary analysis of the current rulemaking.

Table 8.2.2 Equipment Classes Evaluated for the Automatic Commercial Ice-Making Equipment Standard Life-Cycle Cost and Payback Period Analysis

Description (Equipment Family, Cooling Method, Size, Production Method)	Abbreviation
Ice-Making Head, Water-Cooled, Small, Batch	IMH-W-Small-B
Ice-Making Head, Water-Cooled, Medium, Batch	IMH-W-Med-B
Ice-Making Head, Water-Cooled, Large, Batch	IMH-W-Large-B
Ice-Making Head, Air-Cooled, Small, Batch	IMH-A-Small-B
Ice-Making Head, Air-Cooled, Large, Batch	IMH-A-Large-B
Remote-Condensing Unit, Small, Batch	RCU-Small-B
Remote-Condensing Unit, Large, Batch	RCU-Large-B
Self-Contained Unit, Water-Cooled, Small, Batch	SCU-W-Small-B
Self-Contained Unit, Water-Cooled, Large, Batch	SCU-W-Large-B
Self-Contained Unit, Air-Cooled, Small, Batch	SCU-A-Small-B
Self-Contained Unit, Air-Cooled, Large, Batch	SCU-A-Large-B
Ice-Making Head, Water-Cooled, Small, Continuous	IMH-W-Small-C
Ice-Making Head, Water-Cooled, Large, Continuous	IHM-W-Large-C
Ice-Making Head, Air-Cooled, Small, Continuous	IMH-A-Small-C
Ice-Making Head, Air-Cooled, Large, Continuous	IMH-A-Large-C
Remote-Condensing Unit, Small, Continuous	RCU-Small-C
Remote-Condensing Unit, Large, Continuous	RCU-Large-C
Self-Contained Unit, Water-Cooled, Small, Continuous	SCU-W-Small-C
Self-Contained Unit, Water-Cooled, Large, Continuous	SCU-W-Large-C
Self-Contained Unit, Air-Cooled, Small, Continuous	SCU-A-Small-C
Self-Contained Unit, Air-Cooled, Large, Continuous	SCU-A-Large-C

Eleven of the equipment classes in Table 8.2.2 are subject to standards set by the Energy Policy and Conservation Act (EPCA) as amended by the Energy Policy Act of 2005 (EPACT 2005), and the other ten primary equipment classes have not yet been subject to a standard set by legislation or by DOE. Table 8.2.3 presents the baseline energy consumption values and the baseline MSPs used in the LCC and PBP analysis for the representative sizes for each of the 21 primary equipment classes. Preliminary TSD chapter 5 explains how energy use and MSP varies by harvest capacity. Table 8.2.3 also identifies whether DOE obtained the baseline from the engineering analysis, for equipment with no existing standards, or set it at the standards baseline, for equipment covered under existing standards, as explained in chapter 7. As discussed in chapter 5, for new equipment on the market today that is not covered by existing U.S. standards, DOE set the baseline at levels approximating the least efficient equipment that could potentially be available. Baseline energy consumption values presented in this section provide energy use per 100 lb of ice produced. Chapter 7 discusses the methodology to calculate annual energy consumption using these values.

Table 8.2.3 Baseline Energy Consumption Levels and Estimated MSP Values for the Representative Automatic Commercial Ice-Making Equipment Units of All 21 Primary Equipment Classes

Equipment Class	Baseline Energy Consumption <i>kWh/100 lb ice</i>	Manufacturer Selling Price \$	Baseline Type
IMH-W-Small-B	7.80	2,085	Standards Baseline
IMH-W-Med-B	5.03	3,453	Standards Baseline
IMH-W-Large-B	4.00	6,641	Standards Baseline
IMH-A-Small-B	10.26	2,089	Standards Baseline
IMH-A-Large-B	6.40	4,051	Standards Baseline
RCU-Small-B	8.85	3,602	Standards Baseline
RCU-Large-B	5.10	7,064	Standards Baseline
SCU-W-Small-B	11.40	2,258	Standards Baseline
SCU-W-Large-B	7.60	2,269	Standards Baseline
SCU-A-Small-B	18.00	2,258	Standards Baseline
SCU-A-Large-B	9.80	2,263	Standards Baseline
IMH-W-Small-C	8.10	3,435	Engineering Baseline
IMH-W-Large-C	5.10	4,849	Engineering Baseline
IMH-A-Small-C	10.30	2,882	Engineering Baseline
IMH-A-Large-C	6.30	4,849	Engineering Baseline
RCU-Small-C	9.50	3,819	Engineering Baseline
RCU-Large-C	5.50	5,704	Engineering Baseline
SCU-W-Small-C*	9.50	0	Engineering Baseline
SCU-W-Large-C	6.30	2,223	Engineering Baseline
SCU-A-Small-C	18.00	2,211	Engineering Baseline
SCU-A-Large-C	9.80	3,129	Engineering Baseline

*DOE was not able to identify any existing products of the SCU-W-Small-C equipment class in ice maker databases. Hence, this equipment class was not analyzed, directly or by extrapolation.

8.2.2.2 Candidate Standard-Level Energy Consumption and Manufacturer Selling Price Increases

The candidate standard level MSP increase is the change in MSP associated with producing equipment at higher efficiency levels. DOE estimated increases in MSP as a function of equipment efficiency for each of the 21 primary equipment classes^c. The engineering analysis established a series of MSP increases for each standard level. Table 8.2.4 presents the increase in MSP corresponding to each efficiency level for each primary equipment class.

Table 8.2.5 presents the energy consumption of the representative units belonging to each of the 21 primary equipment classes that DOE selected for the engineering analysis.

^c Available data shows there are no existing SCU-W-Small-C products available, so this class is not currently defined in the models; however, it is considered a valid equipment class and, to be consistent, is included as a primary equipment class.

Table 8.2.4 Baseline Manufacturer Selling Prices for Representative Automatic Commercial Ice-Making Equipment Units of the 21 Primary Equipment Classes and Incremental Manufacturer Selling Prices for All Efficiency Levels Within the Equipment Classes

Product Class	Increase in MSP by Efficiency Level 2010\$						
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
IMH-W-Small-B	\$2,085	\$40	\$48				
IMH-W-Med-B	\$3,453	\$31					
IMH-W-Large-B	\$6,641	\$15	\$23				
IMH-A-Small-B	\$2,089	\$13	\$30	\$69			
IMH-A-Large-B	\$4,051	\$15	\$113	\$158			
RCU-Small-B	\$3,602	\$15	\$63	\$85			
RCU-Large-B	\$7,064	\$20	\$101	\$129			
SCU-W-Small-B	\$2,258	\$13	\$34	\$51	\$69		
SCU-W-Large-B	\$2,269	\$13	\$25	\$34	\$43	\$54	\$84
SCU-A-Small-B	\$2,258	\$13	\$39	\$56	\$70	\$78	
SCU-A-Large-B	\$2,263	\$21	\$44	\$58	\$75		
IMH-W-Small-C	\$3,435	\$6	\$15	\$25	\$34	\$98	
IMH-W-Large-C	\$4,849	\$23	\$35	\$63	\$156		
IMH-A-Small-C	\$2,882	\$26	\$44	\$61	\$79	\$203	
IMH-A-Large-C	\$4,849	\$31	\$43	\$54	\$65	\$158	\$270
RCU-Small-C	\$3,819	\$11	\$85				
RCU-Large-C	\$5,704	\$13	\$129				
SCU-W-Small-C	\$0						
SCU-W-Large-C	\$2,223	\$5	\$15	\$25	\$28		
SCU-A-Small-C	\$2,211	\$30	\$58	\$64			
SCU-A-Large-C	\$3,129	\$0	\$46	\$81	\$123	\$169	\$419

* Blank cells imply there are no associated efficiency levels.

Table 8.2.5 Energy Consumption Values for Representative Automatic Commercial Ice-Making Equipment Units of the 21 Primary Equipment Classes and All Efficiency Levels Within the Equipment Classes

Product Class	Total Energy Usage <i>kWh/100 lb ice</i>						
	Level 1	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
IMH-W-Small-B	7.80	7.02	6.71				
IMH-W- Med -B	5.03	4.53					
IMH-W-Large-B	4.00	3.60	3.56				
IMH-A-Small-B	10.26	9.23	8.72	8.21			
IMH-A-Large-B	6.40	5.76	5.44	5.12			
RCU-Small-B	8.85	8.05	7.52	7.39			
RCU-Large-B	5.10	4.64	4.34	4.26			
SCU-W-Small-B	11.40	10.60	9.69	9.12	8.66		
SCU-W-Large-B	7.60	7.07	6.46	6.08	5.70	5.47	4.64
SCU-A-Small-B	18.00	16.74	15.30	14.40	13.50	12.96	
SCU-A-Large-B	9.80	9.11	8.33	7.84	7.35		
IMH-W-Small-C	8.10	7.29	6.89	6.48	6.08	5.43	
IMH-W-Large-C	5.10	4.59	4.34	4.08	3.88		
IMH-A-Small-C	10.30	9.27	8.76	8.24	7.73	7.21	
IMH-A-Large-C	6.30	5.67	5.36	5.04	4.73	4.41	4.10
RCU-Small-C	9.50	8.81	7.93				
RCU-Large-C	5.50	5.10	4.59				
SCU-W-Small-C	9.50						
SCU-W-Large-C	6.30	6.08	5.70	5.32	5.17		
SCU-A-Small-C	18.00	16.74	15.30	14.76			
SCU-A-Large-C	9.80	9.11	8.33	7.84	7.35	6.86	6.27

* Blank cells imply there are no associated efficiency levels.

8.2.2.3 Overall Markup

As discussed in preliminary TSD chapter 6, Markups for Equipment Price Determination, DOE calculated overall markup and applied it to the equipment MSP to calculate the equipment purchase price for customers. DOE calculated baseline markups to convert baseline MSP to baseline customer purchase price and incremental markups to convert the increments in MSP into increments in customer purchase price. DOE used these markup values in the LCC and PBP analysis for calculation of baseline and higher efficiency equipment price to customers.

8.2.2.4 Installation Cost

Most automatic commercial ice makers are installed in fairly standard configurations, which helps in estimating the cost of installation. DOE defines installation cost as a one-time fixed cost that incorporates the labor and materials required to fully install an automatic commercial ice maker. DOE assumed that the installation cost does not vary with efficiency levels in any equipment class. For the preliminary analysis, DOE assumed that the engineering design options do not impact the installation cost within an equipment class and, therefore, within a given equipment class, the installation cost will not vary with efficiency level. Installation cost may vary from one equipment class to another. If engineering design options change, DOE can vary installation cost with efficiency level if technologies warrant an adjustment. Because costs that do not vary with efficiency level do not affect the LCC, PBP, or national impact analysis results, DOE estimated the installation cost in the preliminary analysis

very simply as a fixed percentage of the total MSP for the baseline efficiency level for a given equipment class, set at 10 percent for the preliminary analysis.

Table 8.2.6 shows installation cost indices for installation costs in each of the 50 states and the District of Columbia, and the weighted average for the entire United States. These are used to adjust the national installation cost to reflect differences by state. The state-level data are based on data published by RS Means for major U.S. cities.¹⁰ To arrive at an average index for each state, DOE first weighted the city indices in each state by their population. DOE used state-level population weights for 2010 from the U.S. Census Bureau⁴ to calculate a weighted-average index for each state from the RS Means census data.

Table 8.2.6 Installation Cost Indices (National Value = 100.0)

State	Index	State	Index	State	Index
Alabama	58.7	Kentucky	81.4	North Dakota	57.9
Alaska	113.9	Louisiana	65.7	Ohio	96.9
Arizona	86.6	Maine	68.4	Oklahoma	58.8
Arkansas	62.2	Maryland	92.7	Oregon	106.8
California	131.0	Massachusetts	128.2	Pennsylvania	128.2
Colorado	83.9	Michigan	109.4	Rhode Island	116.8
Connecticut	122.0	Minnesota	126.3	South Carolina	40.2
Delaware	125.6	Mississippi	61.1	South Dakota	46.4
Dist. of Columbia	102.6	Missouri	105.4	Tennessee	76.9
Florida	73.5	Montana	78.0	Texas	63.6
Georgia	72.2	Nebraska	86.3	Utah	75.9
Hawaii	117.5	Nevada	108.4	Vermont	68.7
Idaho	72.4	New Hampshire	90.5	Virginia	73.9
Illinois	142.8	New Jersey	137.4	Washington	110.9
Indiana	87.5	New Mexico	75.5	West Virginia	92.2
Iowa	88.7	New York	170.1	Wisconsin	106.4
Kansas	77.4	North Carolina	40.3	Wyoming	60.4

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 cost. DOE derived the customer equipment price for any given standard level by multiplying the baseline MSP by the baseline markup and adding to it the product of the incremental MSP and the incremental markup. Because MSPs, 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.

The weighted average costs for the IMH-A-Small-B equipment class are presented below for the baseline level at national average markup rates and national average installation costs for illustration purposes. DOE used the baseline MSP and the standard-level MSP increases as the starting points for determining the total installed cost (values are taken directly from Table 8.2.3 and Table 8.2.4). DOE used the baseline and incremental markups, the sales tax, and installation cost to convert the MSPs into total installed costs for cases where the incremental installation cost is held flat. As an example, Table 8.2.7 summarizes the weighted average or mean costs and markups necessary for determining the weighted average baseline and standard-level total installed costs.

Table 8.2.7 Costs and Markups for Determination of Weighted Average Total Installed Costs (IMH-A-Small-B)

Variable	Weighted Average or Mean Value
Baseline MSP	\$2,089.00
Standard-Level MSP Increase (Efficiency Level 4)	\$68.75
Overall Markup Factor–Baseline	1.879
Overall Markup Factor–Incremental	1.301
Installation Cost–Baseline	\$360
Installation Cost Factor, for U.S. Average	1.000
Price Learning Factor	0.983

*Installation cost applied to the baseline unit, with no incremental installation cost.

The calculation below for the baseline (Level 1) and for a higher efficiency level (Level 4) IMH-A-Small-B equipment class illustrates how DOE derived the weighted average total installed cost based on the data shown in Table 8.2.7. For the baseline product, DOE calculated the total installed cost at national average conditions as follows:^d

$$\begin{aligned}
 IC_{BASE\ IMH-A-Small-B} &= EQP_{BASE\ IMH-A-Small-B} + INST_{BASE\ IMH-A-Small-B} \times ISTINDEX \\
 &= MFG_{BASE\ IMH-A-Small-B} \times Price\ Learning\ Coef_{Analysis\ Year} \\
 &\quad \times MU_{BASE\ IMH-A-Small-B} \times Sales\ Tax_{State} \\
 &\quad + INST_{BASE\ IMH-A-Small-B} \times ISTINDEX \\
 &= \$2,089 \times (0.983) \times (1.75215) \times (1.0726) + \$360 \times (1.00) \\
 &= \$3,860 + \$360 \\
 &= \$4,220
 \end{aligned}$$

Eq. 8.3

Where:

$IC_{BASE\ IMH-A-Small-B}$ = total installed cost of IMH-A-Small-B equipment at baseline efficiency level (\$),

$EQP_{BASE\ IMH-A-Small-B}$ = equipment purchase price of IMH-A-Small-B equipment at baseline efficiency level (\$),

$INST_{BASE\ IMH-A-Small-B}$ = installation cost of IMH-A-Small-B equipment at baseline efficiency level (\$),

$MFG_{BASE\ IMH-A-Small-B}$ = MSP of IMH-A-Small-B equipment at baseline efficiency level (\$),

$MU_{BASE\ IMH-A-Small-B}$ = overall baseline markup for equipment class IMH-A-Small-B, and

$ISTINDEX$ = location dependent multiplier on installation cost; approximately 1.0 at a national average.

DOE calculated the total installed cost for the higher efficiency level (Efficiency Level 4) using an incremental MSP. DOE applied an incremental markup factor to the incremental

^d Note that the numbers shown in Eq. 8.3 have been rounded and do not exactly match the numbers in the analysis.

increases in MSP. The Level 4 price is equal to the baseline price calculated above, plus the MSP increment for a higher efficiency level, multiplied by the incremental markup.

As an example, DOE calculated the national average, Level 4, total installed cost ($IC_{IMH-A-Small-BLEVEL4}$) as follows:^e

$$\begin{aligned}
 IC_{IMH-A-Small-BLEVEL4} &= EQP_{IMH-A-Small-BLEVEL4} + INST_{IMH-A-Small-BLEVEL4} \times ISTINDEX \\
 &= \\
 &MFG_{BASE\ IMH-A-Small-B} \times Price\ Learning\ Coef_{Analysis\ Year} \times \\
 &MU_{BASE\ IMH-A-Small-B} + \\
 &\Delta MFG_{IMH-A-Small-BLEVEL4} \times Price\ Learning\ Coef_{Analysis\ Year} \times \\
 &MU_{IMH-A-Small-BLEVEL4} \times Sales\ Tax_{State} + INST_{IMH-A-Small-BLEVEL4} \times ISTINDEX \\
 &= \$2,054 \times (1.75215) \times 1.0726 + \$68 \times (1.21329) + \$360 \times (1.000) \\
 &= \$4,308
 \end{aligned}$$

Eq. 8.4

Where:

$IC_{IMH-A-Small-BLEVEL4}$ = total installed cost of IMH-A-Small-B equipment at Efficiency Level 4 (\$),

$EQP_{IMH-A-Small-BLEVEL4}$ = equipment price of IMH-A-Small-B equipment at Efficiency Level 4 (\$),

$INST_{IMH-A-Small-BLEVEL4}$ = installation cost of IMH-A-Small-B equipment at Efficiency Level 4 (\$),

$\Delta MFG_{IMH-A-Small-BLEVEL4}$ = incremental increase in MSP of IMH-A-Small-B equipment at Efficiency Level 4 compared to equipment at baseline efficiency level (\$), and

$MU_{IMH-A-Small-BLEVEL4}$ = incremental markup for equipment class IMH-A-Small-B.

Table 8.2.8 presents the weighted average equipment price, installation cost, and total installed costs for the IMH-A-Small-B equipment classes at the baseline level and each higher efficiency level examined.

Table 8.2.8 Weighted Average Equipment Price, Installation Cost, and Total Installed Costs for IMH-A-Small-B at U.S. Average Conditions (2010\$)*

Efficiency Level	Equipment Price (MSP)	Installation Cost	Total Installed Cost
1 (Baseline)	\$2,053.92	\$359.88	\$4,219.97
2	\$2,066.21	\$359.88	\$4,235.97
3	\$2,083.41	\$359.88	\$4,258.36
4	\$2,121.51	\$359.88	\$4,307.94

*Numbers provided in this table are taken directly from the LCC analysis, and thus differ from those provided above in the text due to rounding.

^e The numbers shown in Eq. 8.4 have been rounded and do not exactly match the numbers used in the analysis.

8.2.3 Operating-Cost Inputs

DOE defines the operating cost as the sum of energy cost, water cost, repair cost, and maintenance cost, or:

$$OC = EC + WC + RC + MC$$

Eq. 8.5

Where:

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

The remainder of this section describes the variables that DOE used to calculate operating costs for automatic commercial ice makers. Table 8.2.9 shows the inputs used to determine operating costs.

Table 8.2.9 Inputs Used to Determine Operating Costs

Electricity price (cents/kWh)
Water/wastewater price (\$/1,000 gallons)
Electricity and water price trends
Repair cost (\$)
Maintenance cost (\$)
Lifetime (years)
Discount rate (%)
Effective date of standard
Baseline electricity consumption (kWh/100 lb ice)
Baseline water consumption (gallons of water/100 lb ice)
Standard case electricity consumption (kWh/100 lb ice)
Standards water consumption (gallons of water/100 lb ice)

8.2.3.1 Electricity Price Analysis

This section describes the electricity price analysis used to develop the energy portion of the annual operating costs (price multiplied by electricity consumption) for automatic commercial ice makers used in various commercial building types.

Subdivision of the Country. Because of the wide variation in electricity consumption patterns, wholesale costs, and retail rates across the country, DOE considered regional differences in electricity prices. DOE divided the United States into the 50 states and the District of Columbia. DOE used average effective commercial electricity prices at the state level from the EIA web page entitled *Electric Sales, Revenue, and Average Price*.² At the time DOE developed the LCC/PBP model, the latest available prices from this source were for the calendar year 2009 in 2009\$. DOE adjusted these to represent 2010\$ prices using the gross domestic product (GDP) price deflator from *AEO2011*.³ Table 8.2.10 provides the adjusted electricity prices.

Table 8.2.10 Commercial Electricity Prices by State (2010 cents/kWh)

State	Commercial Electricity Price <i>cents/kWh</i>	State	Commercial Electricity Price <i>cents/kWh</i>	State	Commercial Electricity Price <i>cents/kWh</i>
Alabama	10.14	Kentucky	7.70	North Dakota	6.87
Alaska	14.59	Louisiana	7.76	Ohio	9.74
Arizona	9.44	Maine	12.66	Oklahoma	6.82
Arkansas	7.63	Maryland	12.08	Oregon	7.56
California	13.54	Massachusetts	15.51	Pennsylvania	9.63
Colorado	8.22	Michigan	9.32	Rhode Island	13.79
Connecticut	17.01	Minnesota	7.99	South Carolina	8.82
Delaware	12.09	Mississippi	9.59	South Dakota	7.21
Dist. of Col.	13.08	Missouri	7.02	Tennessee	9.70
Florida	10.87	Montana	8.40	Texas	9.75
Georgia	9.02	Nebraska	7.40	Utah	7.02
Hawaii	22.06	Nevada	10.74	Vermont	13.05
Idaho	6.55	New Hampshire	14.68	Virginia	8.13
Illinois	9.07	New Jersey	13.96	Washington	7.02
Indiana	8.40	New Mexico	8.48	West Virginia	6.83
Iowa	7.62	New York	15.65	Wisconsin	9.66
Kansas	7.94	North Carolina	8.05	Wyoming	7.35

DOE recognized that different kinds of businesses typically use electricity in different amounts at different times of the day, week, and year, and therefore experience different effective prices. To make this adjustment, DOE used the 2003 Commercial Buildings Energy Consumption Survey (CBECS) data set to identify the average prices paid by the seven kinds of businesses in this analysis compared with the average prices paid by all commercial customers. Because it isn't explicitly recognized as a CBECS building type, DOE identified multi-line retail by identifying retail stores for which the data suggest the presence of walk-in refrigeration and other commercial refrigeration equipment.^f Eq. 8.6 shows how DOE calculated the prices paid by the seven types of businesses in each state or district:

$$EPRICE_{COM\ BLDGTYPE\ STATE\ 2010} = EPRICE_{COM\ STATE\ 2010} \times \left(\frac{EPRICE_{BLDGTYPE\ US\ 2003}}{EPRICE_{COM\ US\ 2003}} \right) \quad \text{Eq. 8.6}$$

Where:

- $EPRICE_{COM\ BLDGTYPE\ STATE\ 2010}$ = average commercial sector electricity price in a specific building type (such as health care, food sales, and foodservice) in a specific state in 2010,
- $EPRICE_{COM\ STATE\ 2010}$ = average commercial sector electricity price in a specific state in 2010,
- $EPRICE_{BLDGTYPE\ US\ 2003}$ = national average commercial-sector electricity price in a specific building type in 2003 CBECS, and
- $EPRICE_{COM\ US\ 2003}$ = national average commercial sector electricity price in 2003 CBECS.

Table 8.2.11 shows the resulting commercial building electricity price ratios.

^f Automatic commercial ice makers are not explicitly captured by the CBECS database, so commercial refrigeration is used as a proxy for buildings of interest to this analysis.

Table 8.2.11 Derived National Average Commercial Electricity Prices and Ratios by Business Type

Business Type	Electricity Price <i>dollars/kWh</i>	Ratio of Electricity Price to Average Price for all Commercial Buildings
HealthCare	\$0.07222	0.910
Lodging	\$0.08583	1.082
Food Service	\$0.07722	0.973
Retail	\$0.07262	0.915
Education	\$0.07962	1.003
Food Sales	\$0.08467	1.067
Office	\$0.07664	0.966
All commercial buildings	\$0.07936	1.000

Source: CBECS 2003.

The derived ratio equates commercial electricity prices by building type to the overall average commercial building price. DOE then combined the derived ratio with state-by-state commercial rates to derive a series of prices for each state and for each building type. DOE forecast future prices 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 2010 population in each state.⁴

8.2.3.2 Electricity Price Trend

The electricity price trend provides the relative change in electricity prices through the year 2045. Estimating future electricity prices is difficult, especially considering that there are efforts in many states throughout the country to restructure the electricity supply industry.

DOE applied a projected trend in national average electricity prices to each customer's energy prices based on the *AEO2011* price scenarios. The discussion in this chapter refers to the 2010 reference price scenario. In the LCC analysis, DOE can analyze the following four scenarios:

1. Constant (real) energy prices at 2010 values (*i.e.*, a constant index of 1.0)
2. *AEO2011*, High Economic Growth (“AEO2011 High Growth” in Figure 8.2.1)
3. *AEO2011*, Reference Case (“AEO2011 Reference” in Figure 8.2.1)
4. *AEO2011*, Low Economic Growth (“AEO2011 Low Growth” in Figure 8.2.1)

Figure 8.2.1 shows the trends for the *AEO2011* reference case, high growth, and low growth price projections. DOE extrapolated the values for the later years, after 2035—the last year of the *AEO2011* forecast. DOE used the price trend from 2025 to 2035 of each forecast scenario to establish prices for the years 2036 to 2045.

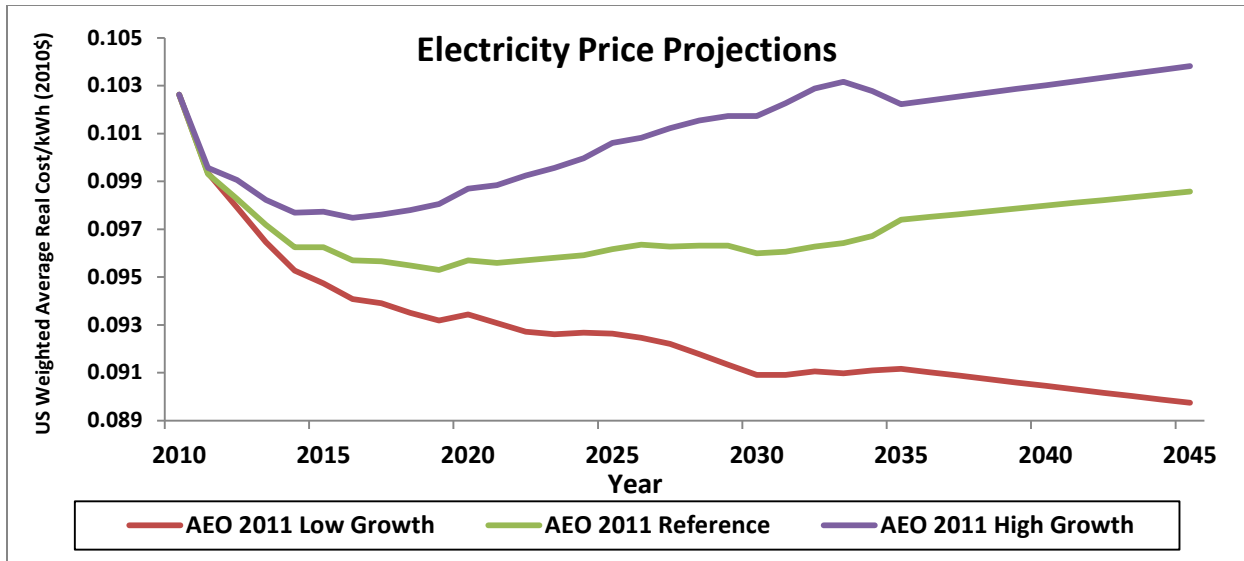


Figure 8.2.1 Electricity Price Trends for Commercial Rates to 2045

The default electricity price trend scenario used in the LCC analysis is the trend from the *AEO2011* Reference Case, shown in Figure 8.2.1. The LCC model spreadsheets have the capability to analyze the *AEO2011* High Growth, *AEO2011* Low Growth price trends, and constant energy prices for additional sensitivity analysis.

8.2.3.3 Repair Cost

The repair cost is the average annual cost to the customer for replacing or repairing components in the automatic ice maker that have failed. In the absence of available data for the preliminary analysis, DOE has approximated the repair costs as a 3-percent fixed percentage of the total baseline MSP for each equipment class and assumed the repair costs stay constant within an equipment class for all efficiency levels. Forthcoming analyses of the engineering design options may indicate for specific technologies used, marginal repair and replacement costs for higher efficiency levels may be warranted.

8.2.3.4 Maintenance Cost

The maintenance cost is the cost to the customer of ensuring proper equipment operation even if there are no specific equipment failures (*e.g.*, checking and maintaining refrigerant levels, replacing filters, checking water distribution lines for leaks, cleaning, sanitizing, and descaling). The maintenance cost does not include the costs associated with the replacement or repair of components that have failed (as discussed above).

DOE approximated annualized maintenance costs for automatic commercial ice makers as a 3-percent fixed percentage of the total MSP for each equipment class. Because data were not available to indicate how maintenance costs vary with equipment efficiency level, DOE used a 3-percent preventative maintenance costs that remain constant across all equipment efficiency levels. Table 8.2.12 shows the annualized maintenance costs by equipment class for each efficiency level.

Table 8.2.12 Annualized Maintenance Costs by Equipment Class for Each Efficiency Level

Equipment Class	Annualized Maintenance Costs for LCC by Efficiency Level \$/yr
IMH-W-Small-B	\$107.76
IMH-W- Med -B	\$178.46
IMH-W-Large-B	\$343.22
IMH-A-Small-B	\$107.96
IMH-A-Large-B	\$209.36
RCU-Small-B	\$186.16
RCU-Large-B	\$365.08
SCU-W-Small-B	\$116.70
SCU-W-Large-B	\$117.27
SCU-A-Small-B	\$116.70
SCU-A-Large-B	\$116.96
IMH-W-Small-C	\$177.53
IMH-W-Large-C	\$250.61
IMH-A-Small-C	\$148.95
IMH-A-Large-C	\$250.61
RCU-Small-C	\$197.37
RCU-Large-C	\$294.79
SCU-W-Small-C	\$0.00
SCU-W-Large-C	\$114.89
SCU-A-Small-C	\$114.27
SCU-A-Large-C	\$161.71

8.2.3.5 Lifetime

As discussed in section 8.1.2, DOE defines lifetime as the age at which a typical automatic commercial ice maker is retired from service. DOE estimated equipment lifetime based on discussions with industry experts, and concluded that a typical lifetime of 8.5 years is appropriate for most automatic commercial ice makers. Because some equipment has remaining useful life, there is a market for equipment that has been removed from service. DOE understands, however, that the salvage value to the original purchaser is generally very low, and thus has not taken this 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 discount rates for the automatic commercial ice maker analysis by estimating the cost of capital for the types of companies that purchase automatic commercial ice makers. The cost of capital is commonly used to estimate the present value of cash flows to be derived from for a project or investment. Most companies use both debt and equity capital to fund investments, so their overall 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).⁵ The CAPM, among the most widely used of models that estimate the cost of equity financing, assumes that the cost of equity is proportional to the amount of systematic risk associated with a particular company. The cost of equity financing tends to be high when a

company faces a large degree of systematic risk and it tends to be low when the company faces a small degree of systematic risk.

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

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

$$k_e = R_f + (\beta \times ERP)$$

Eq. 8.7

Where:

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

DOE defined the risk-free rate as the 40-year geometric average yield on long-term government bonds. DOE calculated the risk-free rate using Federal Reserve data for the period 1971 to 2010,⁶ with a resulting rate of 6.74 percent. DOE used a 3.23-percent estimate for the ERP based on a calculation with data downloaded from the Damodaran Online⁷ site (discussion forthcoming).

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

$$k_d = R_f + R_a,$$

Eq. 8.8

Where:

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

The risk adjustment factor depends on the variability of stock returns represented by standard deviations in stock prices—DOE took values from Damodaran Online individual company cost of capital worksheets (discussion forthcoming).⁸

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

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

Eq. 8.9

Where:

k = the (nominal) cost of capital (%),

k_e = the expected rate of return on equity (%),

k_d = the expected rate of return on debt (%),

w_e = the proportion of equity financing in total annual financing, and

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

The cost of capital is a nominal rate, because it includes anticipated future inflation in the expected returns from stocks and bonds. The real discount rate or WACC deducts expected inflation (r) from the nominal rate. DOE calculated expected inflation (3.83 percent) over the same 1971–2010 historical period used for the other data calculations.

To estimate the WACC of automatic commercial ice maker purchasers, DOE used a data set of companies involved in each of the building types being analyzed, drawn from a database of U.S. companies given on the Damodaran Online individual company worksheet cited earlier. The Damodaran database includes most of the publicly traded companies in the United States.

DOE divided the companies into categories according to their type of activity (*e.g.*, foodservice or food sales). DOE used financial information for all of the firms in the Damodaran database that would be likely to utilize one of the seven building types in the use of an automatic commercial ice maker. DOE used all observations from the Damodaran data set for which complete data were available. One building type, education, was not identifiable in the list of publicly traded companies in Damodaran's database and, therefore, DOE calculated WACC using an approach explained below.

Table 8.2.13 outlines the building type and ownership categories as well as the number of companies used for determining discount rates. For five of the seven building categories, there is a mixture of large companies with stock traded on major U.S. stock exchanges, and smaller companies that are not publicly traded—*e.g.*, single-store or small, local chains of convenience stores or restaurants. The cost of capital for small, independent grocers, convenience store franchisees, gasoline station owner-operators, and others with more limited access to capital is more difficult to determine than for publicly traded companies. Individual credit worthiness varies considerably, and some franchisees have access to the financial resources of the franchising corporation. During research leading up to the 2009 commercial refrigeration equipment rulemaking, DOE contacted a sample of commercial bankers regarding cost for debt financing and the contacts yielded an estimate for the small operator weighted cost of capital of about 200 to 300 basis points (2 to 3 percent) above the rates for large grocery chains. DOE adopted the average value of 2.5 percent for use for small operators across all seven building types.

Table 8.2.13 Derivation of Typical Discount Rates by Building Type*

Building Type Description	Major Chain		Local or Non-Chain		Governmental		Discount Rate	No. Obs.**
	WACC	Percent of Stock	Small Firm Premium	Percent of Stock	Muni Bond Rate	Percent of Stock		
HealthCare	8.09%	68%	2.50%	0%	2%	32%	3.82%	5
Lodging	11.07%	50%	2.50%	50%	2%	0%	5.26%	46
Foodservice	9.00%	50%	2.50%	50%	2%	0%	5.61%	50
Retail	8.17%	75%	2.50%	25%	2%	0%	4.06%	12
Education	3.70%	25%	2.50%	0%	2%	75%	2.05%	21
Food Sales	7.69%	80%	2.50%	20%	2%	0%	3.37%	25
Office	8.99%	25%	2.50%	50%	2%	25%	4.64%	913

Source: Pacific Northwest National Laboratory (PNNL) WACC calculations applied to firms sampled from the Damodaran Online web site. Assumptions for weighting factors for convenience and food service reflect lack of reliable data sources.

*In the preliminary stage, DOE evaluated only major chain and governmental firms. In the NOPR stage, DOE will calculate the discount rates as shown above.

** Obs. are the number of observations that DOE used in calculating discount rate data.

For buildings with an education application, DOE identified little representative data in the Damodaran database. Data in the Damodaran database is representative of privately operated schools, but the database lacks data on cost of capital for public schools. DOE used data from representative 10-year AA municipal bonds as a proxy for the Damodaran data.^{11, g}

8.2.3.7 Compliance Date of Standard

The compliance date is the future date when a new standard will become operative (*i.e.*, the date on which manufacturers must be compliant with the new DOE standard). Under 42 U.S.C. 6313(d)(2)(B), the compliance date of any new energy conservation standard for automatic commercial ice makers will be 3 years after the final rule is published. DOE calculated the LCC for all customers as if they each would purchase a new automatic commercial ice maker in the year the standard takes effect. Consistent with its published regulatory agenda, DOE assumed that the final rule would be issued in 2013 and that, therefore, the new standards would take effect in 2016, and used these dates in the preliminary analysis. For the LCC analysis, the year of equipment purchase is 2016. However, all dollar values are expressed in 2010\$.

8.3 PAYBACK PERIOD INPUTS

8.3.1 Definition

As previously stated in section 8.1, the PBP is the amount of time it takes the customer to recover the higher purchase price of more energy efficient equipment through lower operating costs. Numerically, the PBP is the ratio of the increase in purchase cost to the decrease in annual operating expenditures. This type of calculation is known as a “simple” payback period because it does not take into account changes in operating cost over time or the time value of money, that is, the calculation is done at an effective discount rate of zero percent.

^g DOE realizes the education data in the preliminary analysis is not a robust set of data and will refine the data during the NOPR stage.

The equation for PBP is:

$$PBP = \Delta IC / \Delta OC$$

Eq. 8.10

Where:

PBP = payback period in years,

ΔIC = difference in the total installed cost between the more efficient standard level and the baseline equipment, and

ΔOC = difference in annual (first year) operating costs.

PBPs greater than the life of the product mean that the increased total installed cost of the more energy efficient equipment is not recovered in reduced operating costs over the life of the equipment, even when no discount rate is applied.

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 customer's equipment price and the installation cost. The inputs to the operating costs are the annual energy and water costs, the annual repair cost, and the annual maintenance cost. The PBP calculation uses the same inputs as the LCC analysis described in section 8.2, except that electricity price trends and discount rates are not required because the PBP is a "simple" (undiscounted) payback and the required electricity and water prices are only for the year in which a new efficiency standard is to take effect—in this case, the year 2016. The electricity price used in the PBP calculation of electricity cost was the price projected for 2016, expressed in 2010\$. Discount rates are not used in the PBP calculation.

8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

The results of the LCC and PBP analysis are presented in this section. Mean values of LCC savings and PBP are presented along with a summary of the distribution of these values.

8.4.1 Life-Cycle Cost Results

Figure 8.4.1 shows the change in LCC over the four efficiency levels for the IMH-A-Small-B equipment class. The LCC values on this chart are mean values obtained from the LCC analysis. This curve is presented here as an example to illustrate the typical relationship between installation cost and LCC values over all the efficiency levels in an equipment class. The installed costs increase steadily from the baseline to the highest possible efficiency level and the LCCs decrease from Level 1 to the highest possible efficiency level.

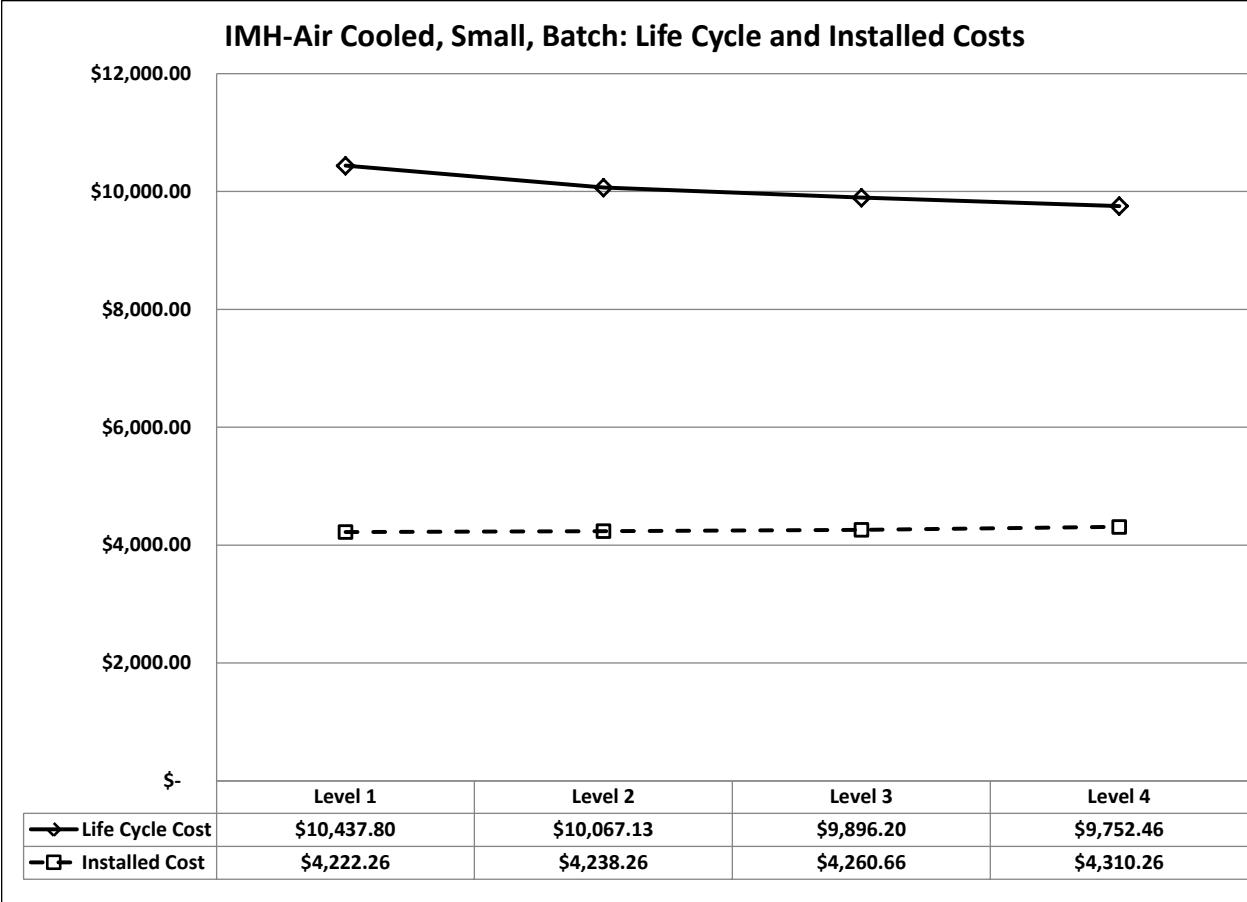


Figure 8.4.1 LCC and Installed Cost Variation over Efficiency Levels for IMH-A-Small-B Equipment Class

As stated earlier, DOE calculated the LCC savings for a range of building types, WACCs, and geographic locations. Figure 8.4.2 illustrates an example of the ranges of LCC savings for the IMH-A-Small-B equipment class. Appendix 8B includes similar plots of LCC savings for all equipment classes analyzed. Table 8.4.1 presents the numerical values associated with Figure 8.4.2. Figure 8.4.2 illustrates the mean and median values on the plot using red and blue markers, respectively. The elongated, large rectangular box represents the 25th and 75th percentile values. The lower edge of the elongated rectangle represents 25th percentile, which means that 25 percent of the customers would experience LCC savings of \$291 or less if the standard were set at Level 2, \$319 or less in LCC savings if the standards were set at Level 3, and so on. The median value of LCC savings is equal to the 50th percentile. The upper edge of the elongated rectangle represents the 75th percentile. The two ends of the vertical black line for each efficiency level represent the 5th percentile (lower end) and 95th percentile (upper end).

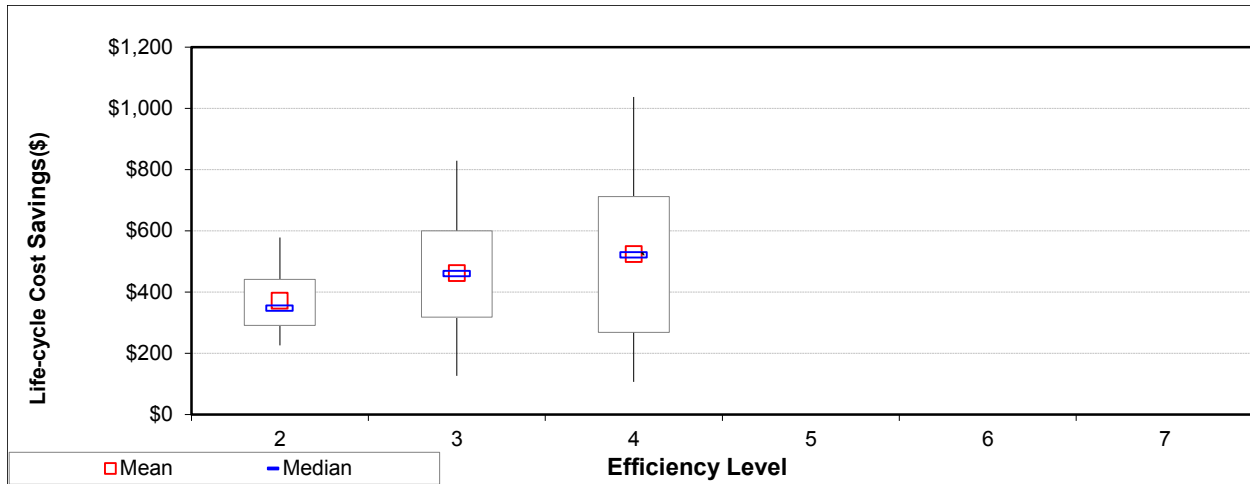


Figure 8.4.2 Ranges of LCC Savings for All the Efficiency Levels for the Equipment Class IMH-A-Small-B

Table 8.4.1 LCC Savings Distribution Results for Equipment Class IMH-A-Small-B

Efficiency Level		2	3	4
LCC Savings 2010\$	Mean	\$372.16	\$462.01	\$524.15
	Median (50th Percentile)	\$348.07	\$460.47	\$521.70
	5th Percentile	\$226.31	\$126.57	\$106.88
	25th Percentile	\$291.39	\$318.79	\$268.25
	75th Percentile	\$441.73	\$599.79	\$711.57
	95th Percentile	\$578.60	\$828.82	\$1,036.61

Table 8.4.2 and Table 8.4.3 summarize the mean and median LCC savings, respectively, for all equipment classes analyzed.

Table 8.4.2 Mean LCC Savings for All Equipment Classes and Efficiency Levels

Equipment Class	Mean LCC Savings 2010\$*					
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
IMH-W-Small-B	243.76	278.98				
IMH-W- Med -B	498.73					
IMH-W-Large-B	735.46	801.32				
IMH-A-Small-B	372.16	462.01	524.15			
IMH-A-Large-B	625.28	675.10	883.14			
RCU-Small-B	683.77	856.93	933.54			
RCU-Large-B	842.31	1,062.49	1,092.62			
SCU-W-Small-B	94.85	146.25	173.65	214.35		
SCU-W-Large-B	185.35	399.47	450.19	453.86	425.55	659.02
SCU-A-Small-B	158.97	229.31	331.49	438.47	456.83	
SCU-A-Large-B	146.05	231.09	336.82	416.00		
IMH-W-Small-C	–	399.60	528.44	618.43	813.26	
IMH-W-Large-C	–	–	286.81	204.51		
IMH-A-Small-C	367.90	427.57	425.33	442.86	333.04	
IMH-A-Large-C	–	–	384.30	570.01	848.66	1,101.70
RCU-Small-C	–	678.35				
RCU-Large-C	–	810.55				
SCU-W-Small-C**						
SCU-W-Large-C	–	–	132.25	186.12		
SCU-A-Small-C	–	–	–			
SCU-A-Large-C	–	–	–	132.44	188.73	(39.92)

* A value of "–" means that there are no affected customers at this efficiency level. Values on this table represent LCC savings for customers affected by the standard, and a "–" means that in the base-case efficiency distribution, all customers are expected to be purchasing equipment that is more efficient. Blank cells mean no LCC savings were calculated for this efficiency level because design options were unavailable to constitute an additional efficiency level.

** Data available to DOE shows there are no existing SCU-Water-Small-Continuous products available, so this class is not currently defined in the models.

Table 8.4.3 Median LCC Savings for All Equipment Classes and Efficiency Levels

Equipment Class	Median LCC Savings 2010\$*					
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
IMH-W-Small-B	226.28	275.43				
IMH-W-Med-B	466.08					
IMH-W-Large-B	688.76	750.19				
IMH-A-Small-B	348.07	460.47	521.70			
IMH-A-Large-B	585.86	677.26	853.14			
RCU-Small-B	640.06	843.71	904.41			
RCU-Large-B	788.03	1,045.99	1,082.80			
SCU-W-Small-B	88.27	133.98	161.54	196.34		
SCU-W-Large-B	173.39	373.85	453.34	449.88	329.55	562.37
SCU-A-Small-B	148.38	205.33	307.10	406.73	443.57	
SCU-A-Large-B	135.71	210.18	312.52	393.65		
IMH-W-Small-C	–	369.77	458.61	513.17	690.54	
IMH-W-Large-C	–	–	267.18	154.46		
IMH-A-Small-C	340.61	430.28	314.08	325.66	219.38	
IMH-A-Large-C	–	–	359.31	526.71	802.95	1,030.05
RCU-Small-C	–	632.06				
RCU-Large-C	–	755.36				
SCU-W-Small-C**						
SCU-W-Large-C	–	–	123.55	173.92		
SCU-A-Small-C	–	–	–			
SCU-A-Large-C	–	–	–	122.16	168.64	(75.06)

* A value of “–” means that there are no affected customers at this efficiency level. Values on this table represent LCC savings for customers affected by the standard, and a “–” means that in the base-case efficiency distribution, all customers are expected to be purchasing equipment that is more efficient. Blank cells mean no LCC savings were calculated for this efficiency level because design options were unavailable to constitute an additional efficiency level.

** Data available to DOE shows there are no existing SCU-Water-Small-Continuous products available, so this class is not currently defined in the models.

8.4.2 Payback Period Results

Figure 8.4.3 presents the distribution of the PBP results for efficiency levels above the baseline for the equipment class IMH-A-Small-B. Table 8.4.4 presents the numerical values associated with this plot. The red marker represents the mean and the blue marker represents the median PBP for each efficiency level. The lower edge of the elongated rectangular box represents the 25th percentile, which means that 25 percent of the customers would experience a PBP of 0.27 years or less if the energy conservation standard were set at Level 2, 0.43 years or less if the energy conservation standard were set at Level 3, and so on. The upper edge of the rectangular box represents the 75th percentile. The two ends of the vertical line represent the 5th percentile (lower end) and 95th percentile (upper end). Table 8.4.5 and Table 8.4.6 summarize the mean and median PBPs, respectively, for all efficiency levels for all the analyzed equipment classes.

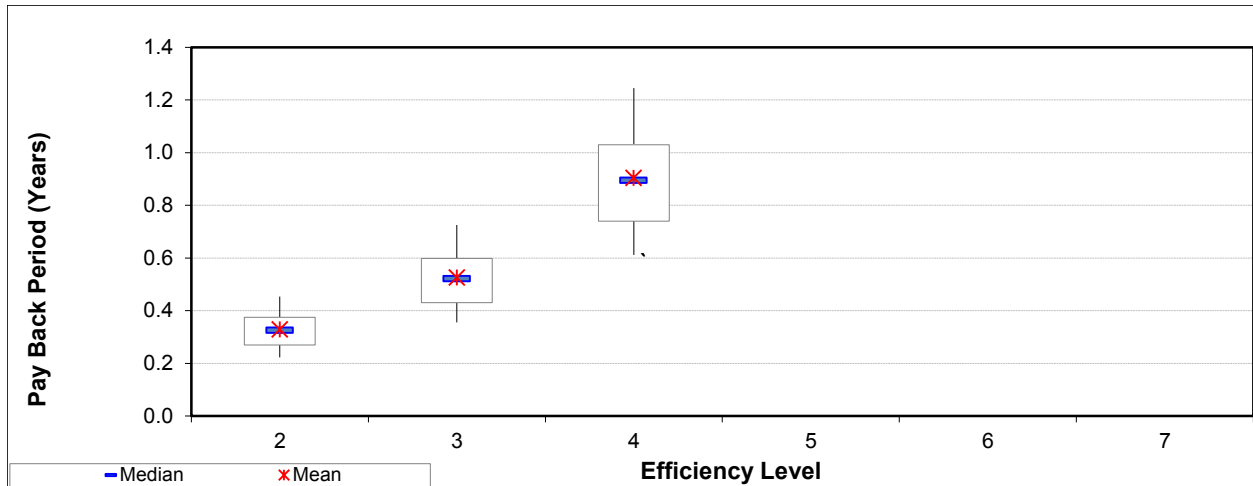


Figure 8.4.3 Mean Payback Period for All Efficiency Levels for the Equipment Class IMH-A-Small-B

Table 8.4.4 Payback Period Distribution Results for IMH-A-Small-B

		Efficiency Level		
		2	3	4
Payback Period years	Mean	0.33	0.53	0.90
	Median (50th Percentile)	0.33	0.52	0.90
	5th Percentile	0.22	0.36	0.61
	25th Percentile	0.27	0.43	0.74
	75th Percentile	0.37	0.60	1.03
	95th Percentile	0.45	0.72	1.25

Table 8.4.5 Mean Payback Period for All Equipment Classes and Efficiency Levels

Equipment Class	Mean Payback Period <i>years*</i>					
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
IMH-W-Small-B	1.38	1.17				
IMH-W-Med-B	0.59					
IMH-W-Large-B	0.20	0.28				
IMH-A-Small-B	0.33	0.53	0.90			
IMH-A-Large-B	0.24	1.19	1.24			
RCU-Small-B	0.22	0.54	0.67			
RCU-Large-B	0.23	0.71	0.83			
SCU-W-Small-B	1.15	1.45	1.65	1.85		
SCU-W-Large-B	0.63	0.59	0.60	0.60	0.68	0.76
SCU-A-Small-B	0.73	1.06	1.15	1.14	1.13	
SCU-A-Large-B	1.25	1.20	1.19	1.24		
IMH-W-Small-C	0.08	0.12	0.16	0.17	0.37	
IMH-W-Large-C	0.36	0.37	0.50	1.03		
IMH-A-Small-C	0.67	0.74	0.78	0.80	1.71	
IMH-A-Large-C	0.40	0.36	0.35	0.33	0.67	0.99
RCU-Small-C	0.19	0.63				
RCU-Large-C	0.17	0.77				
SCU-W-Small-C**						
SCU-W-Large-C	0.61	0.68	0.69	0.65		
SCU-A-Small-C	1.75	1.57	1.45			
SCU-A-Large-C±	-	0.85	1.12	1.35	1.55	3.20

* Blank cells imply there are no associated efficiency levels.

** Data available to DOE shows there are no existing SCU-Water-Small-Continuous products available, so this class is not currently defined in the models.

± The “-” value for Level 2 indicates that the first efficiency level improvement has a \$0 capital cost.

Table 8.4.6 Median Payback Period for All Equipment Classes and Efficiency Levels

Equipment Class	Median payback period years*					
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
IMH-W-Small-B	1.37	1.16				
IMH-W-Med-B	0.59					
IMH-W-Large-B	0.20	0.27				
IMH-A-Small-B	0.33	0.52	0.90			
IMH-A-Large-B	0.23	1.17	1.23			
RCU-Small-B	0.22	0.54	0.67			
RCU-Large-B	0.23	0.71	0.82			
SCU-W-Small-B	1.14	1.44	1.64	1.83		
SCU-W-Large-B	0.63	0.59	0.59	0.60	0.68	0.76
SCU-A-Small-B	0.72	1.05	1.14	1.13	1.12	
SCU-A-Large-B	1.24	1.19	1.18	1.23		
IMH-W-Small-C	0.08	0.12	0.15	0.17	0.37	
IMH-W-Large-C	0.35	0.37	0.49	1.02		
IMH-A-Small-C	0.66	0.73	0.77	0.79	1.70	
IMH-A-Large-C	0.40	0.36	0.34	0.33	0.67	0.98
RCU-Small-C	0.19	0.62				
RCU-Large-C	0.17	0.76				
SCU-W-Small-C**						
SCU-W-Large-C	0.61	0.67	0.68	0.65		
SCU-A-Small-C	1.74	1.55	1.43			
SCU-A-Large-C±	-	0.84	1.11	1.34	1.53	3.17

* Blank cells imply there are no associated efficiency levels.

** Data available to DOE shows there are no existing SCU-Water-Small-Continuous products available, so this class is not currently defined in the models.

± The “-” value for Level 2 indicates that the first efficiency level improvement has a \$0 capital cost.

8.4.3 Rebuttable Presumption Payback Period

EPCA establishes a rebuttable presumption for automatic commercial ice-making equipment. (42 U.S.C. 6295(o)(2)(B)(iii) and 42 U.S.C. 6313(d)(4)) The rebuttable presumption states that a standard is economically justified if the Secretary finds that the additional cost to the customer 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 customer will receive as a result of the standard, as calculated under the applicable test procedure. This rebuttable presumption test is an alternative path to establishing economic justification.

To evaluate the rebuttable presumption, DOE estimated the additional cost of purchasing more efficient, standards-compliant equipment, and compared this cost to the value of the energy saved during the first year of operation of the equipment. DOE interprets that the increased cost of purchasing standards-compliant equipment includes the cost of installing the equipment for use by the purchaser. DOE calculated the rebuttable presumption payback period (RPBP), or the ratio of (a) the increase in installed cost above the baseline efficiency level, to (b) the first year energy cost savings. When RPBP is less than 3 years, the rebuttable presumption is satisfied; when RPBP is equal to or more than 3 years, the rebuttable presumption is not satisfied. This

PBP calculation does not include other components of the annual operating cost of the equipment (*i.e.*, maintenance costs and repair costs). The RPBBs calculated can thus be different from the PBPs calculated in section 8.4.2.

DOE calculated the RPBBs for the range of installed costs and energy prices discussed in sections 8.4.1 and 8.4.2, which are representative of the same seven building types and all 50 states plus the District of Columbia. DOE calculated the RPBP for each higher efficiency level within each equipment class.

Table 8.4.7 shows the nationally averaged RPBBs calculated for all equipment classes and efficiency levels.

Table 8.4.7 Rebuttable Presumption Payback Periods by Efficiency Level and Equipment Class

Equipment Class	Rebuttable Payback Period <i>years*</i>					
	Level 2	Level 3	Level 4	Level 5	Level 6	Level 7
IMH-W-Small-B	1.25	1.06				
IMH-W- Med -B	0.54					
IMH-W-Large-B	0.18	0.25				
IMH-A-Small-B	0.30	0.48	0.82			
IMH-A-Large-B	0.21	1.07	1.13			
RCU-Small-B	0.20	0.49	0.61			
RCU-Large-B	0.21	0.65	0.75			
SCU-W-Small-B	1.04	1.31	1.50	1.67		
SCU-W-Large-B	0.57	0.54	0.54	0.55	0.62	0.69
SCU-A-Small-B	0.66	0.96	1.04	1.04	1.02	
SCU-A-Large-B	1.13	1.09	1.07	1.12		
IMH-W-Small-C	0.07	0.11	0.14	0.15	0.33	
IMH-W-Large-C	0.32	0.34	0.45	0.94		
IMH-A-Small-C	0.60	0.67	0.70	0.72	1.55	
IMH-A-Large-C	0.36	0.36	0.36	0.36	0.36	0.36
RCU-Small-C	0.17	0.57				
RCU-Large-C	0.15	0.69				
SCU-W-Small-C**						
SCU-W-Large-C	0.55	0.61	0.62	0.59		
SCU-A-Small-C	1.59	1.42	1.31			
SCU-A-Large-C±	-	0.77	1.01	1.22	1.40	2.90

* Blank cells indicate that there are no associated efficiency levels.

** Data available to DOE shows there are no existing SCU-Water-Small-Continuous products available, so this class is not currently defined in the models.

± The “-” value for Level 2 indicates that the first efficiency level improvement has a \$0 capital cost.

8.5 DETAILED RESULTS

Appendix 8B presents detailed results from the LCC analysis. Plots similar to Figure 8.4.2 and Figure 8.4.3 are presented in the appendix for all equipment classes. In addition, summary tables with all the necessary data in one table for each equipment class are presented.

Table 8.5.1 is the summary table for IMH-A-Small-B equipment class. This table presents the mean values of installed costs, annual operating costs, LCC, LCC savings, and median PBP values for all the efficiency levels. It also presents the percentage of customers who experience net cost, no impact, and net benefit. The average LCC savings and the percentage of customers experiencing a net benefit or cost are based on a range of efficiency choices. In the base case, DOE does not assume that all customers buy equipment at the baseline efficiency (Level 1). DOE assumes that some are buying at higher efficiency levels. The LCC savings is an average of the savings achieved by customers who, in the base case, were buying less efficient equipment than the efficiency level examined. DOE assumed that customers with no impact in the base case are already buying more efficient equipment, so the efficiency level in question would not affect those customers.

Table 8.5.1 Summary of Results of LCC and PBP Analysis for IMH-A-Small-B Equipment Class

Efficiency Level Number	Efficiency Level <i>kWh/yr</i>	Life-Cycle Cost, All Customers			Life-Cycle Cost Savings				Median Payback Period, <i>years</i>
		Installed Cost <i>2010\$</i>	Total Discounted Operating Cost <i>2010\$</i>	LCC, All Customers <i>2010\$</i>	Affected Customers' Average Savings <i>2010\$</i>	% of Customers that Experience			
						Net Cost %	No Impact %	Net Benefit %	
1	5639	4222	6216	10438	0	NA	NA	NA	NA
2	5078	4238	5829	10067	372	0	41	59	0.33
3	4797	4261	5636	9896	462	0	24	76	0.52
4	4516	4310	5442	9752	524	0	8	92	0.90

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