CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

8.1 INTRODUCTION

This chapter of the technical support document (TSD) presents the U.S. Department of Energy's (DOE)'s life-cycle cost (LCC) and payback period (PBP) analyses. It describes the method DOE used for analyzing the economic impacts of possible standards on consumers. The effect of standards on consumers includes a change in operating expense (usually decreased) and a change in purchase price (usually increased). The LCC and PBP analyses produce two basic outputs to describe the effect of standards on consumers:

- **LCC** is the total (discounted) cost that a consumer pays over the lifetime of the equipment, including purchase price, installation cost, and operating expenses.

- **PBP** measures the amount of time it takes consumers to recover the estimated higher purchase expense of more energy efficient equipment through lower operating costs.

This chapter presents inputs and results for the LCC and PBP analyses, as well as key variables, current assumptions, and computational equations. DOE performed the calculations discussed here using Microsoft Excel spreadsheets, which are accessible on DOE's website (*http://www.eere.energy.gov/buildings/appliance_standards/*). Inputs to the LCC and PBP are discussed in sections 8.2 and 8.3, respectively, of this chapter. Results for the LCC and PBP are presented in section 8.4, with sensitivity results in section 8.5. Details regarding and instructions for using the spreadsheets are discussed in Technical Support Document (TSD) Appendix 8-A.

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

Recognizing that several inputs to the determination of consumer LCC and PBP are either variable or uncertain, DOE conducted the LCC and PBP analysis by modeling both the uncertainty and variability in the inputs using Monte Carlo simulation and probability distributions. DOE developed LCC and PBP spreadsheet models incorporating both Monte Carlo simulation and probability distributions by using a Microsoft Excel spreadsheet combined with Crystal Ball (a commercially available add-on program).

In addition to characterizing several of the inputs to the analysis with probability distributions, DOE also developed a sample of end-use applications for each of the eight representative units. These end-use applications determine the use profile of the motor and the economic characteristics of the motor owner (by sector). Table 8.1.1 shows the market shares of each application for all representative units across all sectors (see TSD chapter 7 for details)[1].

Table 8.1.1 Application Shares by Representative Unit

Representative Unit		Application					
		Air compressors	**Fans**	**Pumps**	**Material Handling and Processing**	**Other**	**Fire Pumps**
1	NEMA Design B, T-frame, 5 hp, 4 poles, enclosed	1.8%	22.5%	22.3%	12.0%	41.4%	0.00%
2	NEMA Design B, T-frame, 30 hp, 4 poles, enclosed	2.2%	26.6%	33.0%	6.8%	31.4%	0.00%
3	NEMA Design B, T-frame, 75 hp, 4 poles, enclosed	5.6%	25.7%	34.2%	10.6%	23.9%	0.00%
4	NEMA Design C, T-frame, 5 hp, 4 poles, enclosed	0.0%	25.0%	0.0%	25.0%	50.0%	0.0%
5	NEMA Design C, T-frame, 50 hp, 4 poles, enclosed	0.0%	0.0%	28.6%	14.3%	57.1%	0.0%
6	Fire pump, 5 hp, 4 poles, enclosed	0.0%	0.0%	0.0%	0.0%	0.0%	100%
7	Fire pump, 30 hp, 4 poles, enclosed	0.0%	0.0%	0.0%	0.0%	0.0%	100%
8	Fire pump, 75 hp, 4 poles, enclosed	0.0%	0.0%	0.0%	0.0%	0.0%	100%

In each Monte Carlo iteration, for each representative unit, one of the applications is identified by sampling from a distribution of applications for that representative unit. The selected application determines the number of operating hours per year as well as the motor loading. The operating hours and the motor loading for the application are used in the energy use calculation (see TSD chapter 7).

Further, the sector and the Census region are identified by sampling from distributions and they determine the energy price used in the LCC calculation in each simulation. DOE used Energy Information Administration (EIA) data on electricity prices in 2010 for different customer classes and data from the DOE and the U.S. Department of Agriculture to establish the variability in energy pricing by Census region.

Also, the sector to which the motor belongs determines the discount rate used in the LCC calculation in each simulation.

DOE also used data from the literature on motor loading and motor application characteristics to estimate the variability of annual energy use. Due to the large range of applications and motor use characteristics considered in the LCC and PBP analysis, the range of annual energy use and energy prices can be quite large. Thus, although the annual energy use and energy pricing are known for each sampled motor, their variability across all motors contributes to the range of LCCs and PBPs calculated for any particular standard level.

Results presented at the end of this chapter are based on 10,000 samples per Monte Carlo simulation run. DOE displays the LCC and PBP results as distributions of impacts compared to the base case without standards.

8.1.2 Overview of Life-Cycle Cost and Payback Period Inputs

DOE categorizes inputs to the LCC and PBP analysis as follows: (1) inputs for establishing the initial expense, otherwise known as the total installed cost, and (2) inputs for calculating the operating cost.

The primary inputs for establishing the total installed cost are:

- *Baseline manufacturer selling price*: The price at which the manufacturer sells the baseline equipment, which includes the costs incurred by the manufacturer to produce equipment meeting existing standards.
- *Manufacturer selling price increases*: The change in manufacturer selling price associated with producing equipment to meet a particular standard level.
- *Markups and sales tax*: The markups and sales tax associated with converting the manufacturer cost to a consumer equipment price. The markups and sales tax are described in detail in chapter 6, Markups Analysis.
- *Installation cost*: The cost to the consumer of installing the equipment. The installation cost represents all costs required to install the equipment other than the marked-up consumer equipment price. The installation cost includes labor, overhead, and any miscellaneous materials and parts. Thus, the total installed cost equals the consumer equipment price plus the installation cost.

The primary inputs for calculating the operating cost are:

- *Equipment energy consumption and reactive power*: The equipment energy consumption is the site energy use associated with operating the equipment. Reactive power is power that is reflected back to the electrical system by a change in the phase of alternating current power. TSD Chapter 7, Energy Use Characterization, details how DOE determined the equipment energy consumption based on various data sources.

- *Equipment efficiency*: The equipment efficiency dictates the energy consumption associated with standard-level equipment (i.e., equipment with efficiencies greater than baseline equipment). TSD Chapter 7, Energy Use Characterization, details how energy and reactive power change with increasing equipment efficiency and how equipment efficiency relates to actual equipment energy use.

- *Energy prices*: Energy prices are the prices paid by end-users for energy (i.e., electricity). DOE determined current energy prices based on data from the EIA.

- *Energy price trends*: DOE used the EIA *Annual Energy Outlook 2011* (*AEO2011*)[2] to forecast energy prices into the future. For the results presented in this chapter, DOE used the reference case of *AEO2011* to forecast future energy prices.

- *Repair and maintenance costs*: Repair costs are associated with repairing or replacing components that have failed. Maintenance costs are associated with maintaining the operation of the equipment.

- *Lifetime*: The age at which the equipment is retired from service.

- *Discount rate*: The rate at which DOE discounted future expenditures 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. In the figure below, the yellow boxes indicate the inputs, the green boxes indicate intermediate outputs, and the blue boxes indicate the final outputs (the LCC and PBP).

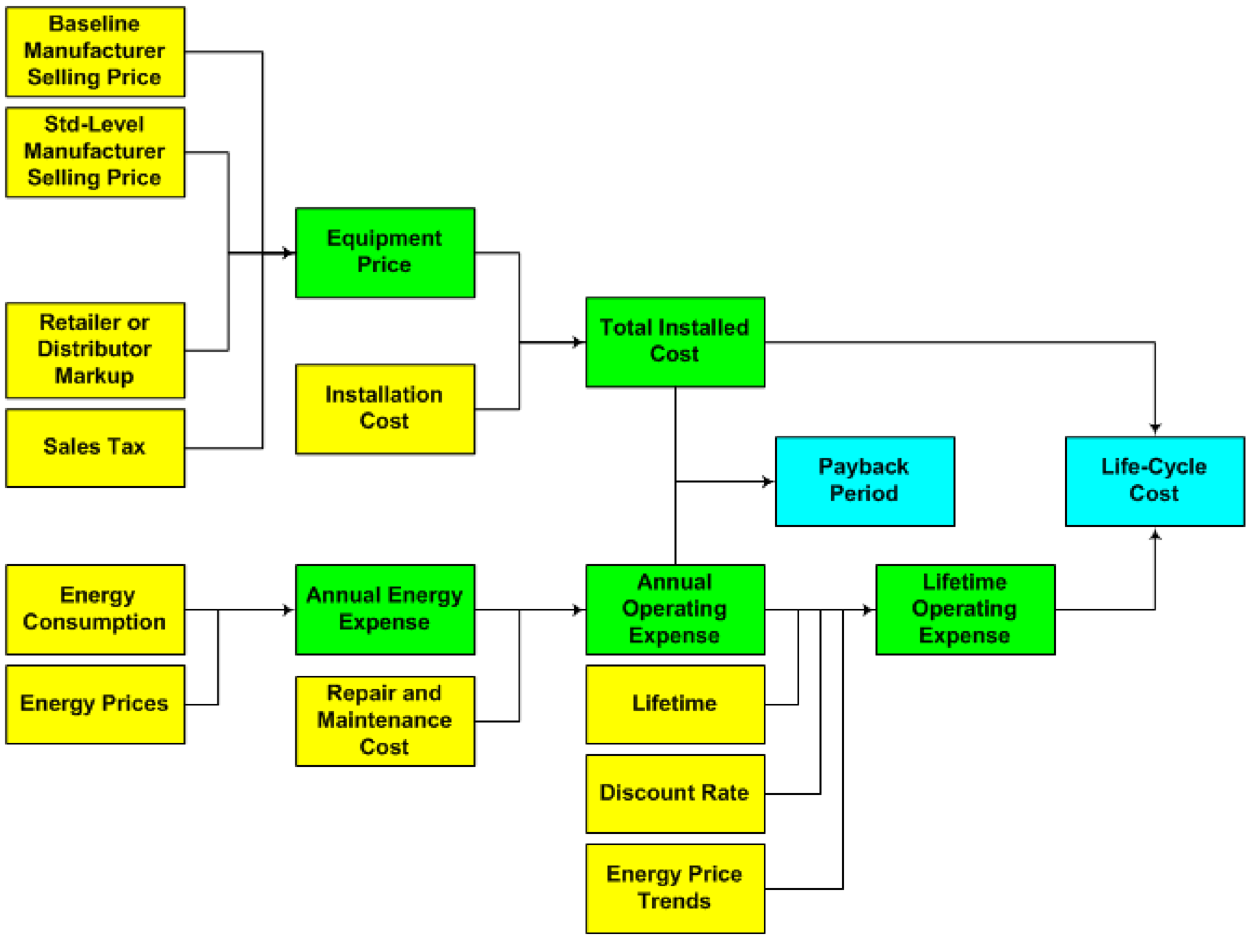

Figure 8.1.1 Flow Diagram of Inputs for the Determination of Life-Cycle Cost and Payback Period

8.2 LIFE-CYCLE COST INPUTS

Life-cycle cost is the total customer expense over the life of a piece of equipment, including purchase expense and operating costs (including energy expenditures). DOE discounts future operating costs to the time of purchase, and sums them over the lifetime of the equipment. DOE defines LCC by the following equation:

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

Where:

LCC = life-cycle cost in dollars,
IC = total installed cost in dollars,
$\sum$ = sum over the lifetime, from year 1 to year N,
N = lifetime of appliance in years,

OC = operating cost in dollars,
r = discount rate, and
t = year for which operating cost is being determined.

DOE gathered most of its data for the LCC and PBP analysis in 2010 and 2011, and updated its inputs to 2011$ using appropriate measures of inflation where necessary. Throughout this TSD, DOE expresses dollar values in 2011$.

Table 8.2.1 is an example of how DOE calculates the LCC and PBP for representative unit 1 (NEMA Design B, T-Frame, 5 HP, 4 poles, enclosed motor). This table summarizes the total installed cost inputs and the operating cost inputs, including the lifetime, discount rate, and energy price trends. DOE characterized all of the total cost inputs with single-point values, but characterized several of the operating cost inputs with probability distributions that capture the input's uncertainty or variability, or both. For those inputs characterized with probability distributions, the values provided in the following table are the average or typical values. Also listed in the following table is the chapter of the TSD where more detailed information on the inputs can be found. The sections following the table discuss total installed cost, operating cost, lifetime, and discount rate.

Table 8.2.1 Inputs for Life-Cycle Cost and Payback Period Analysis: Representative Unit 1

Input	Average or Typical Value	Characterization	TSD Chapter Reference
Total Installed Cost Inputs			
Baseline Manufacturer Cost (2011$)	$324	Price for NEMA Design B, T-Frame, 5 hp, 4 poles, Enclosed Motors. Single-Point Value.	5
Candidate Standard-Level (CSL) Manufacturer Cost Increase (2011$)	CSL 1 = $326 CSL 2 = $358 CSL 3 = $370 CSL 4 = $523 CSL 5 = $579	Price for NEMA Design B, T-Frame, 5 hp, 4 poles, Enclosed Motors.	5
Distribution and OEM Markups	Baseline = 1.52 Incremental = 1.40 Shipping Cost = $0.65/pound	Point value for each distribution channel with 20% variance added	6
Sales Tax	1.0712	Point value	6
Installation Cost	No cost increase with efficiency	No cost increase with efficiency	8
Operating Cost Inputs			
Annual Operating Hours	3,623 hours/year	Full distribution ranging from 0.5 to 8,760 hours per year and with distribution varying by application and sector	7
Annual Energy Use	Baseline use* = 10,448 kWh	Variability based on usage	7
Reactive Power	Baseline = 2.64 kilovolt-amperes reactive	Variability based on usage, load, and power factor	7
Average Energy Prices (2011$)	Industrial = 8.35 ¢/kWh Commercial = 11.18 ¢/kWh Agricultural = 8.52 ¢/kWh	Variability based on application owner types	8
Repair and Maintenance Costs (2011$)	Repair: $448 Maintenance: No cost increase with efficiency	Repair: Costs increase with efficiency Maintenance: No cost increase with efficiency	8
Lifetime	10.1 years	Distribution based in part on annual hours of operation	8
Discount Rate	Industry and agricultural = 5.8% Commercial = 5.7%	Variability based on application owner types	8
Energy Price Trend	*AEO 2011* Release	Two sensitivities: High and Low Energy Price Cases	8

* Annual use provided for baseline equipment only. Annual use decreases with increased equipment efficiency.

8.2.1 Total Installed Cost Inputs

DOE defines the total installed cost, IC, using the following equation:

$$\boldsymbol{IC = EQP + INST}$$

Where:

EQP = equipment price (i.e., customer cost for the equipment only), expressed in dollars, and
INST = installation cost or the customer price to install equipment (i.e., the cost for labor and materials), also in dollars.

The equipment price is based on how the customer (end-user) purchases the equipment. As discussed in TSD chapter 6, Markups for Equipment Price Determination, DOE defined markups and sales taxes for converting manufacturing selling prices into customer equipment prices.

Table 8.2.2 summarizes the inputs for the determination of total installed cost.

Table 8.2.2 Inputs for Total Installed Cost

Baseline Manufacturer Selling Price
Manufacturer Selling Price Increase
Markups and Sales Tax
Installation Cost

The *baseline manufacturer selling price* is the price charged by the manufacturer to produce equipment for the current market. *Manufacturer selling price increase* is the change in manufacturer price associated with producing equipment at a standard level. *Markups and sales tax* convert the manufacturer selling price to a consumer equipment price. The *installation cost* is the cost to the consumer of installing the equipment and represents all costs required to install the equipment other than the marked-up consumer equipment price. The installation cost includes labor, overhead, and any miscellaneous materials and parts. Thus, the total installed cost equals the consumer equipment price plus the installation cost. DOE calculated the total installed cost for baseline products based on the following equation:

$$\begin{aligned} IC_{BASE} &= EQP_{BASE} + INST_{BASE} \\ &= MSP_{MFG} \times MU_{OVERALL\_BASE} + INST_{BASE} \end{aligned}$$

Where:

IC_{BASE} = baseline total installed cost,
EQP_{BASE} = consumer equipment price for baseline models,
$INST_{BASE}$ = baseline installation and shipping cost,

MSP_{MFG} = manufacturer selling price for baseline models, and
$MU_{OVERALL\_BASE}$ = baseline overall markup (product of manufacturer markup, baseline retailer or distributor markup, and sales tax).

DOE calculated the total installed cost for standard-level products based on the following equation:

$$\begin{aligned} IC_{STD} &= EQP_{STD} + INST_{STD} \\ &= \left(EQP_{BASE} + \Delta EQP_{STD}\right) + \left(INST_{BASE} + \Delta INST_{STD}\right) \\ &= \left(EQP_{BASE} + INST_{BASE}\right) + \left(\Delta EQP_{STD} + \Delta INST_{STD}\right) \\ &= IC_{BASE} + \left(\Delta MSP_{MFG} \times MU_{OVERALL\_INCR} + \Delta INST_{STD}\right) \end{aligned}$$

Where:

IC_{STD} = standard-level total installed cost,
EQP_{STD} = consumer equipment price for standard-level models,
$INST_{STD}$ = standard-level installation cost,
EQP_{BASE} = consumer equipment price for baseline models,
ΔEQP_{STD} = change in equipment price for standard-level models,
$INST_{BASE}$ = baseline installation and shipping cost,
$\Delta INST_{STD}$ = change in installation and shipping cost for standard-level models,
IC_{BASE} = baseline total installed cost,
ΔMSP_{MFG} = change in manufacturer selling price for standard-level models, and
$MU_{OVERALL\_INCR}$ = incremental overall markup (product of manufacturer markup, incremental retailer or distributor markup, and sales tax).

DOE found no evidence that installation costs would increase with higher motor energy efficiency. Thus, DOE did not incorporate changes in installation costs for motors that are more efficient than baseline products. In addition, motor installation cost data from *RS Means Electrical Cost Data 2010* show a variation in installation costs according to the motor horsepower (for three-phase electric motors), but not according to efficiency[3]. Therefore, in the preliminary analysis, DOE assumed there is no variation in installation costs between a baseline efficiency motor and a higher efficiency motor.

The remainder of this section provides information about each of the above input variables that DOE used to calculate the total installed cost for electric motors.

8.2.1.1 Projection of Future Product Prices

To derive a price trend for electric motors, DOE obtained historical Producer Price Index (PPI) data for integral horsepower motors and generators manufacturing spanning the time period 1969-2011from the Bureau of Labor Statistics' (BLS).[a] The PPI data reflect nominal

[a] Series ID PCU3353123353123; http://www.bls.gov/ppi/

prices, adjusted for product quality changes. An inflation-adjusted (deflated) price index for integral horsepower motors and generators manufacturing was calculated by dividing the PPI series by the Gross Domestic Product Chained Price Index (see Figure 8.2.1).

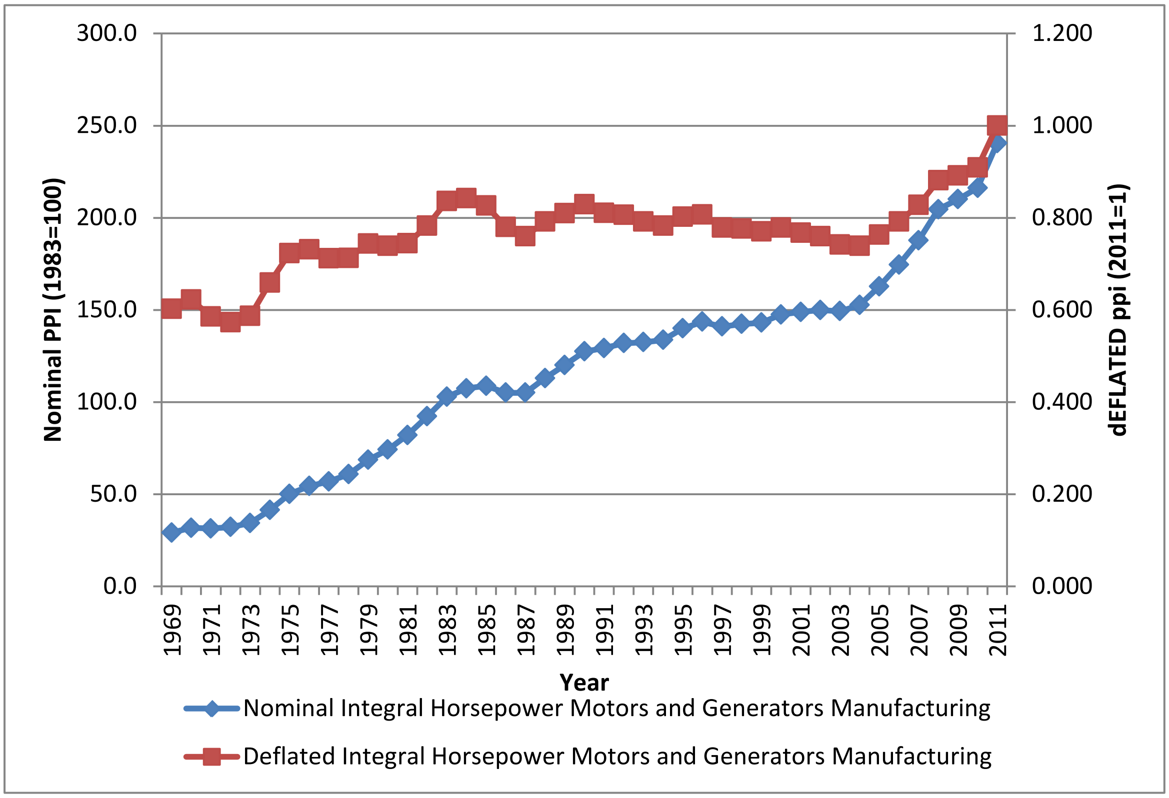

Figure 8.2.1 Historical Nominal and Deflated Producer Price Indexes for Integral Horsepower Motors and Generators Manufacturing

From the mid-1970s to 2005, the deflated price index for electric motors was roughly flat. Since then, the index has risen sharply, primarily due to rising prices of copper and steel products that go into motors (see Figure 8.2.2). The rising prices for copper and steel products were primarily a result of strong demand from China and other emerging economies. Given the slowdown in global economic activity in 2011, DOE believes that the extent to which the trends of the past five years will continue is very uncertain. DOE performed an exponential fit on the deflated price index for electric motors, but the coefficient of determination was relatively low (R^2=0.5). DOE also considered the experience curve approach, in which an experience rate parameter is derived using two historical data series on price and cumulative production, but the time series for historical shipments was not long enough for a robust analysis.

Given the above considerations, DOE decided to use a constant price assumption as the default price factor index to project future motor prices in 2015. Thus, prices forecast for the LCC and PBP analysis are equal to the 2011 values for each efficiency level in each equipment class.

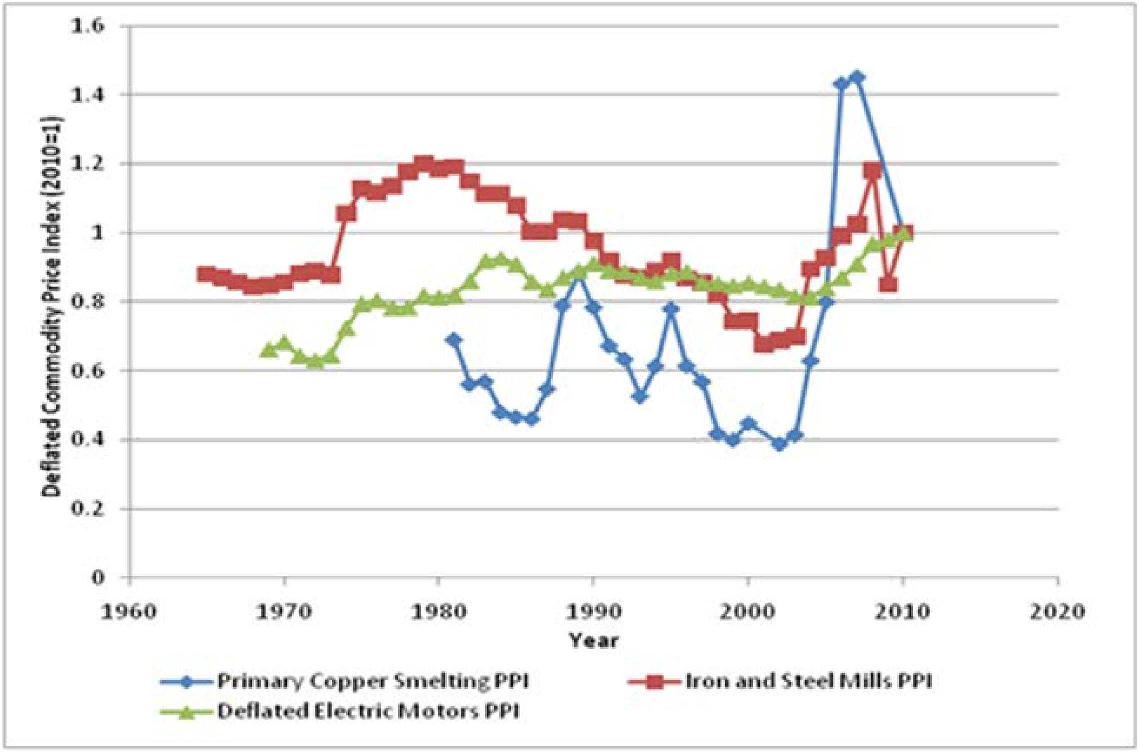

Figure 8.2.2 Historical Deflated Producer Price Indexes for Copper Smelting, Steel Mills Manufacturing and Integral Horsepower Motors and Generators

8.2.1.2 Baseline Manufacturer Selling Price

The engineering analysis provides a baseline manufacturer selling price (MSP) that includes all manufacturer markups (see TSD chapter 5). Table 8.2.3 presents the baseline MSP and the associated energy efficiency for each representative unit analyzed in the engineering analysis.

Table 8.2.3 Engineering Baseline Manufacturer Selling Price

Representative Unit		Baseline Efficiency %	Baseline MSP *2011$*
1	NEMA Design B, T-frame, 5 hp, 4 poles, enclosed	82.5	324
2	NEMA Design B, T-frame, 30 hp, 4 poles, enclosed	89.5	827
3	NEMA Design B, T-frame, 75 hp, 4 poles, enclosed	93.0	1,833
4	NEMA Design C, T-frame, 5 hp, 4 poles, enclosed	87.5	324
5	NEMA Design C, T-frame, 50 hp, 4 poles, enclosed	93.0	1,452
6	Fire pump, 5 hp , 4 poles, enclosed	87.5	326
7	Fire pump, 30 hp, 4 poles, enclosed	92.4	1,044
8	Fire pump, 75 hp, 4 poles, enclosed	94.1	1,994

DOE determined the MSP associated with motors produced at increasing energy efficiency levels for electric motors in the engineering analysis (see TSD chapter 5). Table 8.2.4 through Table 8.2.8 present the MSP, along with the associated energy efficiency for representative units 1 through 5. Representative units 6 through 8 (fire pump electric motors) are analyzed based on the same data for representative units 1 through 3: the efficiency levels and the associated MSPs for candidate standard level (CSL) 1 through 5 for representative units 1 through 3 are the same as baseline through CSL 4 for representative units 6 through 8. (see Table 8.2.4 through Table 8.2.6).

Table 8.2.4 Efficiency and Manufacturer Selling Price Data for Representative Unit 1: NEMA Design B, T-Frame, 5 hp, 4 Poles, Enclosed Motor

Energy Efficiency Level	**Efficiency** *%*	**MSP** *2011$*
Baseline	82.5	324
1	87.5	326
2	89.5	358
3	90.2	370
4	91.0	523
5	91.7	579

Table 8.2.5 Efficiency and Manufacturer Selling Price Data for Representative Unit 2: NEMA Design B, T-Frame, 30 hp, 4 Poles, Enclosed Motor

Energy Efficiency Level	**Efficiency** *%*	**MSP** *2011$*
Baseline	89.5	827
1	92.4	1,044
2	93.6	1,193
3	94.1	1,204
4	94.5	1,936

Table 8.2.6 Efficiency and Manufacturer Selling Price Data for Representative Unit 3: NEMA Design B, 75 hp, 4 Poles, Enclosed Motor

Energy Efficiency Level	**Efficiency** *%*	**MSP** *2011$*
Baseline	93.0	1,833
1	94.1	1,994
2	95.4	2,270
3	95.8	2,581
4	96.2	3,353

5	96.5	3,712

Table 8.2.7 Efficiency and Manufacturer Selling Price Data for Representative Unit 4: NEMA Design C, 5 hp, 4 Poles, Enclosed Motor

Energy Efficiency Level	Efficiency *%*	MSP *2011$*
Baseline	87.5	324
1	89.5	348
2	90.2	522
3	91.0	559

Table 8.2.8 Efficiency and Manufacturer Selling Price Data for Representative Unit 5: NEMA Design C, 50 hp, 4 Poles, Enclosed Motor

Energy Efficiency Level	Efficiency *%*	MSP *2011$*
Baseline	93.0	1,452
1	94.1	1,664
2	94.5	1,992
3	95.0	2,168

Table 8.2.9 shows the baseline and incremental markups estimated for each point in the electric motor supply chain. The overall baseline and incremental markups shown are weighted averages based on the share of shipments in each distribution channel. Refer to TSD chapter 6 for details.

Table 8.2.9 Markups for Electric Motors Covered in this Analysis

Point in Supply Chain	**Baseline***	**Incremental***
Wholesale	1.17	1.10
OEM	1.32	1.29
Retail and Post-OEM	1.00	1.00
Contractor/Installer	1.52	1.40
Sales Tax	1.0712	
Overall	1.63	1.50

* Weighted average of the three distribution channels.

Total Installed Cost: The total installed cost is the sum of the end-user equipment price and the installation cost. Refer back to section 8.2.1 to see the equations that DOE used to calculate the total installed cost for various energy efficiency levels. Table 8.2.10 through Table 8.2.14 present the end-user equipment price, shipping cost, and total installed cost for representative unit 1 through 5. Representative units 6 through 8 (fire pump electric motors) are analyzed based on the same data for representative units 1 through 3 (see Table 8.2.10 through Table 8.2.12).

Specifically, CSL 1 through 5 for representative units 1 through 3 have the same total installed cost as baseline through CSL 4 for representative units 6 through 8.

Table 8.2.10 Representative Unit 1: NEMA Design B, T-Frame, 5 hp, 4 Poles, Enclosed: Consumer Equipment Prices, Shipping Costs, and Total Installed Costs

Energy Efficiency Level	Efficiency *%*	Equipment Price *2011$*	Shipping Cost *2011$*	Total Installed Cost *2011$*
Baseline	82.5	527	57	584
1	87.5	531	57	588
2	89.5	579	72	651
3	90.2	596	69	665
4	91.0	825	84	909
5	91.7	910	89	998

Table 8.2.11 Representative Unit 2: NEMA Design B, T-Frame, 30 hp, 4 Poles, Enclosed: Consumer Equipment Prices, Shipping Costs, and Total Installed Costs

Energy Efficiency Level	Efficiency *%*	Equipment Price *2011$*	Shipping Cost *2011$*	Total Installed Cost *2011$*
Baseline	89.5	1,346	224	1,570
1	92.4	1,700	286	1,986
2	93.6	1,923	354	2,277
3	94.1	1,939	349	2,288
4	94.5	3,036	432	3,468
5	94.5	3,036	432	3,468

Table 8.2.12 Representative Unit 3: NEMA Design B, T-Frame, 75 hp, 4 Poles, Enclosed: Consumer Equipment Prices, Shipping Costs, and Total Installed Costs

Energy Efficiency Level	Efficiency *%*	Equipment Price *2011$*	Shipping Cost *2011$*	Total Installed Cost *2011$*
Baseline	93.0	2,983	480	3,463
1	94.1	3,246	585	3,831
2	95.4	3,659	636	4,296
3	95.8	4,125	651	4,776
4	96.2	5,282	762	6,044
5	96.5	5,820	820	6,640

Table 8.2.13 Representative Unit 4: NEMA Design C, T-Frame, 5 hp, 4 Poles, Enclosed: Consumer Equipment Prices, Shipping Costs, and Total Installed Costs

Energy Efficiency Level	Efficiency *%*	Equipment Price *2011$*	Shipping Cost *2011$*	Total Installed Cost *2011$*
Baseline	87.5	528	55	583
1	89.5	564	64	627
2	90.2	824	79	903
3	91.0	880	82	961

Table 8.2.14 Representative Unit 5: NEMA Design C, T-Frame, 50 hp, 4 Poles, Enclosed: Consumer Equipment Prices, Shipping Costs, and Total Installed Costs

Energy Efficiency Level	Efficiency *%*	Equipment Price *2011$*	Shipping Cost *2011$*	Total Installed Cost *2011$*
Baseline	93.0	2,364	423	2,786
1	94.1	2,682	492	3,173
2	94.5	3,173	499	3,673
3	95.0	3,436	514	3,950

8.2.2 Operating Cost Inputs

DOE defines the operating cost, OC, by the following equation:

$$OC = EC + RC + MC$$

Where:

EC = energy expenditure associated with operating the equipment,
RC = repair cost associated with component failure, and
MC = cost for maintaining equipment operation.

Table 8.2.15 shows the inputs for determining the operating costs. The inputs listed in Table 8.2.15 are also necessary for determining the present value of lifetime operating expenses, which include the energy price trends, equipment lifetime, discount rate, and effective date of the standard.

Table 8.2.15 Inputs for Operating Cost

Annual Energy Consumption
Energy Prices
Repair and Maintenance Costs
Energy Price Trends

Product Lifetime
Discount Rate
Effective Date of Standard

The *annual energy consumption* is the site energy use associated with operating the equipment. *Energy prices* are the prices paid by end-users for energy supply, including both energy and demand charges. Multiplying the annual energy and demand by the appropriate prices yields the annual energy cost. *Repair costs* are associated with repairing or replacing components that have failed, and *maintenance costs* are associated with maintaining the operation of the equipment. DOE used *energy price trends* to forecast energy supply prices into the future and, along with the equipment lifetime and discount rate, to establish the lifetime energy supply costs. The *equipment lifetime* is the age at which the equipment is retired from service. The *discount rate* is the rate at which DOE discounted future expenditures to establish their present value. DOE calculated the operating cost for the baseline equipment based on the following equation:

$$\begin{aligned} OC_{BASE} &= EC_{BASE} + RC_{BASE} + MC_{BASE} \\ &= AEC_{BASE} \times PRICE_{ENERGY} + RC_{BASE} + MC_{BASE} \end{aligned}$$

Where:

OC_{BASE} = baseline operating cost,
EC_{BASE} = energy expenditures associated with operating the baseline equipment, which may include reactive power costs,
RC_{BASE} = repair cost associated with component failure for the baseline equipment,
MC_{BASE} = cost for maintaining baseline equipment operation,
AEC_{BASE} = annual energy consumption for baseline equipment, and
$PRICE_{ENERGY}$ = energy price.

DOE calculated the operating cost for standard-level equipment based on the following equation:

$$\begin{aligned} OC_{STD} &= EC_{STD} + RC_{STD} + MC_{STD} \\ &= AEC_{STD} \times PRICE_{ENERGY} + RC_{STD} + MC_{STD} \\ &= (AEC_{BASE} - \Delta AEC_{STD}) \times PRICE_{ENERGY} + (RC_{BASE} + \Delta RC_{STD}) + (MC_{BASE} + \Delta MC_{STD}) \end{aligned}$$

Where:

OC_{STD} = standard-level operating cost,
EC_{STD} = energy expenditures associated with operating standard-level equipment,
RC_{STD} = repair cost associated with component failure for standard-level equipment,
MC_{STD} = cost for maintaining standard-level equipment operation,

AEC_{STD} = annual energy consumption for standard-level equipment,
$PRICE_{ENERGY}$ = energy price,
ΔAEC_{STD} = decrease in annual energy consumption caused by standard-level equipment,
ΔRC_{STD} = change in repair cost caused by standard-level equipment, and
ΔMC_{STD} = change in maintenance cost caused by standard-level equipment.

The remainder of this section provides information about each of the above input variables that DOE used to calculate the operating costs for electric motors.

8.2.2.1 Annual Energy Consumption

TSD Chapter 7, Energy Use Characterization, details how DOE determined the annual energy consumption for baseline and standard-level equipment.

Table 8.16 through Table 8.18 provide the average annual energy consumption by efficiency level for each representative unit. DOE captured the variability in energy consumption by estimating energy consumption for a variety of motor-using applications.

DOE used several assumptions to account for a possible decrease in efficiency each time the motor is repaired, which would therefore increase the annual energy consumption. First, DOE assumed that NEMA Designs A, B and C medium electric motors are repaired on average after 32,000 hours of operation, which corresponds to a repair frequency of 5, 16, and 15 years in the industrial, commercial, and agricultural sectors, respectively. DOE also assumed that fire pump electric motors are not repaired often because of their low annual operating hours. Second, DOE assumed that one-third of repairs are performed following good practices and therefore do not affect the efficiency of the motor (*i.e.*, there is no degradation of efficiency after repair)[4,5,6]. In addition, DOE assumed that two-thirds of repairs do not follow good practices and that the repair results in a slight decrease in efficiency. Lastly, DOE assumed the efficiency drops by 1 percent in the case of motors of less than 40 hp, and by 0.5 percent in the case of larger motors[7].

Table 8.2.16 Average Annual Electricity Use by Efficiency Level for Representative Units 1, 2, and 3

Representative Unit 1		**Representative Unit 2**		**Representative Unit 3**	
NEMA Design B, T-frame, 5 hp, 4 poles, enclosed		**NEMA Design B, T-frame, 30 hp, 4 poles, enclosed**		**NEMA Design B, T-frame, 75 hp, 4 poles, enclosed**	
Efficiency ***%***	**Energy Use** ***kWh/yr***	**Efficiency** ***%***	**Energy Use** ***kWh/yr***	**Efficiency** ***%***	**Energy Use** ***kWh/yr***
82.5	10,448	89.5	57,642	93.0	204,834
87.5	9,869	92.4	55,912	94.1	202,540
89.5	9,691	93.6	55,021	95.4	198,496
90.2	9,616	94.1	54,492	95.8	197,697

91.0	9,567	94.5	54,326	96.2	197,194
91.7	9,487	94.5	54,326	96.5	196,604

Table 8.2.17 Average Annual Electricity Use by Efficiency Level for Representative Units 4 and 5

Representative Unit 4		Representative Unit 5	
NEMA Design C, T-frame, 5 hp, 4 poles, enclosed		NEMA Design C, T-frame, 50 hp, 4 poles, enclosed	
Efficiency *%*	**Energy Use** *kWh/yr*	**Efficiency** *%*	**Energy Use** *kWh/yr*
87.5	9,987	93.0	89,523
89.5	9,808	94.1	88,507
90.2	9,738	94.5	88,119
91.0	9,630	95.0	87,444

Table 8.2.18 Average Annual Electricity Use by Efficiency Level for Representative Units 6, 7, and 8

Representative Unit 6		Representative Unit 7		Representative Unit 8	
Fire pump, 5 hp, 4 poles, enclosed		Fire pump, 30 hp, 4 poles, enclosed		Fire pump, 75 hp, 4 poles, enclosed	
Efficiency *%*	**Energy Use** *kWh/yr*	**Efficiency** *%*	**Energy Use** *kWh/yr*	**Efficiency** *%*	**Energy Use** *kWh/yr*
87.5	19.6	92.4	1,601	94.1	97,791
89.5	19.2	93.6	1,577	95.4	95,934
90.2	19.1	94.1	1,562	95.8	95,554
91.0	19.0	94.5	1,558	96.2	95,313
91.7	18.8	94.5	1,558	96.5	95,033

8.2.2.2 Energy Prices

To estimate the energy prices faced by motor end-users throughout the United States, DOE uses sector-specific regional electricity prices as well as a statistical distribution of motors across sectors and regions to assign an appropriate electricity price to each motor end-user.

First, DOE distributed the motors across the three sectors using data from an Easton Consultants report[8] (see Table 8.2.19).

Table 8.2.19 Distribution Across Sector by Motor Size

Horsepower Range *hp*	Industry %	Agriculture %	Commercial %
1-5	37	0	63
6-20	26	0	74
21-50	26	0	74
51-100	63	7	30
101-200	76	3	21
201-500	69	3	28

Then, for each sector, DOE distributed the motors in four Census regions based on the following indicators:

- value of shipments of manufactured goods from the Manufacturing Energy Consumption Survey for the industrial sector[9];
- value of shipments of agricultural products from the U.S. Census of Agriculture for the agricultural sector [10]; and
- commercial floor space from the Commercial Building Energy Consumption Survey for the commercial sector[11].

Table 8.2.20 shows the resulting distribution.

Table 8.2.20 Sector Specific Share of Electric Motors by Census Region

Census Region	Agricultural %	Industrial %	Commercial %
Northeast	4.6	8.7	19.5
Midwest	42.8	26.4	25.3
South	29.5	52.5	37.3
West	23.1	12.4	17.9

For each sector, DOE then estimated weighted regional average prices using EIA Form 861 data.[12] These data are published annually and include annual electricity usage in kilowatt-hours (kWh), revenues from electricity sales, and number of consumers for the residential, commercial, and industrial sectors for every utility serving final consumers. The calculation used the most recent EIA data available at the time the analysis was conducted. Table 8.2.21 shows the average agricultural, industrial, and commercial electricity prices in 2010 for each Census region.

Table 8.2.21 Average Electricity Prices in 2010

Census Region	Average Agricultural Price *2011$/kWh*	Average Industrial Price *2011$/kWh*	Average Commercial Price *2011$/kWh*
Northeast	0.103	0.103	0.149
Midwest	0.084	0.084	0.095
South	0.078	0.078	0.100
West	0.094	0.094	0.120
Average (weighted)	0.087	0.087	0.111

8.2.2.3 Energy Price Trends

DOE used price forecasts by the EIA to estimate the trends in electricity prices for all sectors. To arrive at prices in future years, DOE multiplied the average prices described in the preceding section by the forecast of annual average price changes in EIA's *AEO 2011*. To estimate the trend after 2035, DOE followed past guidelines provided to the Federal Energy Management Program by EIA and used the projected average rate of change during 2025–2035 for electricity prices.

As an example, Figure 8.2.3 shows the projected trends in industrial electricity prices based on the *AEO 2011* reference case. For the LCC results presented in this chapter, DOE used only the energy price forecast from the *AEO 2011* reference case.

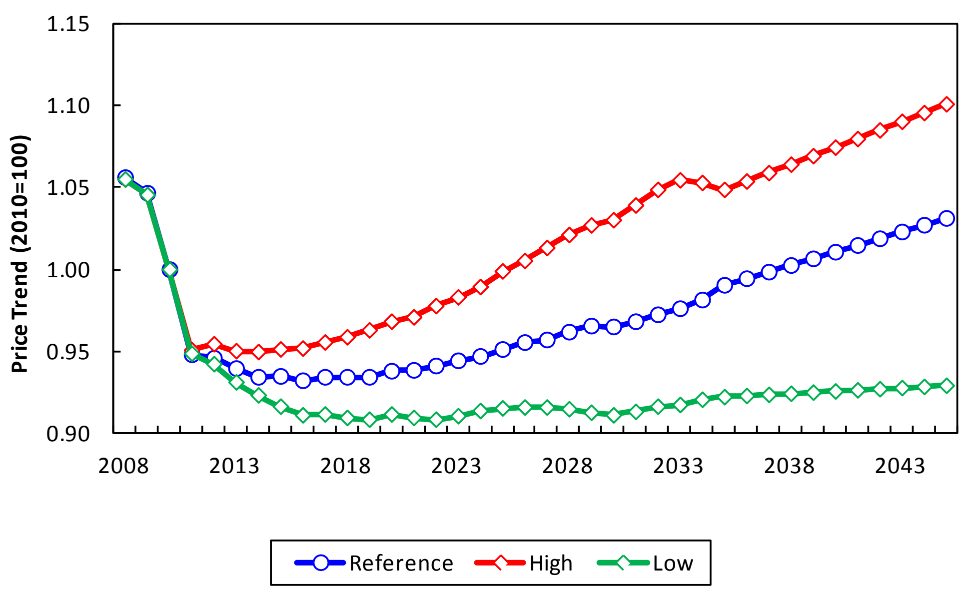

Figure 8.2.3 Industrial Electricity Price Trends

8.2.2.4 Repair and Maintenance Costs

DOE accounted for the differences in repair costs of a higher efficiency motor compared to a baseline-efficiency motor. Based on data from Vaughen's[13], DOE derived a model to estimate repair costs by horsepower, enclosure, and pole, for each CSL level:

$$RepairCost = R(hp, poles, encl, CSL),$$

$$R(hp, poles, encl, CSL) = R'(hp, poles) \cdot R''(encl) \cdot A(CSL),$$

where:

$$R'(hp, poles) = r_2(hp, poles) + r_1(hp, poles) + r_0(poles),$$

with:

$$r_2(hp, poles) = (-0.000005 \cdot poles) \cdot hp^2,$$

$$r_1(hp, poles) = (-0.00027 \cdot poles^2 + 0.00752 \cdot poles + 0.02563) \cdot hp,$$

$$r_0(poles) = (0.00956 \cdot poles^2 + 0.03599 \cdot poles + 0.64067),$$

and,

$$R''(encl) = \begin{cases} 1.0, & Open, \\ 1.2, & Enclosed, \end{cases}$$

and "A" (CSL) is given by Table 8.2.22:

Table 8.2.22 Repair Cost Calculation Parameters

Efficiency level	A
Baseline	0%
CSL 1	15%
CSL 2	25%
CSL 3	30%
CSL 4	35%
CSL 5	40%

Table 8.2.23 shows the resulting repair costs estimates for all horsepower, enclosure, and pole combination for motors with an efficiency level corresponding to CSL 0.

Table 8.2.23 Repair Cost Estimates by Equipment Class (all equipment class groups)

CSL 0	Open				Enclosed			
hp	2 poles	4 poles	6 poles	8 poles	2 poles	4 poles	6 poles	8 poles
1	324	295	376	513	389	354	451	616
1.5	333	302	385	524	399	363	462	629
2	341	310	394	535	409	372	473	642
3	358	325	412	557	430	390	495	668
5	392	356	449	600	470	427	538	720
7.5	434	394	494	655	520	473	592	786
10	475	432	539	709	571	518	647	850
15	559	508	629	816	671	609	754	980
20	642	583	718	923	770	700	862	1,108
25	725	659	807	1,030	870	790	968	1,236
30	807	733	895	1,136	969	880	1,074	1,363
40	971	882	1,071	1,345	1,166	1,059	1,285	1,614
50	1,134	1,030	1,245	1,552	1,361	1,236	1,494	1,863
60	1,295	1,177	1,417	1,757	1,554	1,412	1,700	2,108
75	1,535	1,394	1,672	2,059	1,842	1,673	2,006	2,470
100	1,928	1,751	2,087	2,549	2,313	2,101	2,505	3,059
125	2,312	2,101	2,492	3,024	2,774	2,521	2,990	3,629
150	2,688	2,442	2,885	3,483	3,226	2,931	3,462	4,179
200	3,416	3,104	3,638	4,352	4,100	3,725	4,365	5,222
250	4,112	3,735	4,346	5,158	4,934	4,483	5,215	6,189
300	4,774	4,337	5,009	5,899	5,729	5,205	6,011	7,079
350	5,404	4,909	5,628	6,577	6,484	5,891	6,754	7,893
400	6,000	5,451	6,202	7,192	7,200	6,542	7,443	8,630
450	6,564	5,964	6,732	7,742	7,877	7,157	8,078	9,291
500	7,095	6,447	7,216	8,229	8,515	7,736	8,660	9,874

Table 8.2.24 summarizes the repair cost for representative units by efficiency level.

Table 8.2.24 Summary of Repair Cost for Each Representative Unit by Energy Efficiency Level

Representative Unit		CSL	Repair Cost *2011$*
1	NEMA Design B, T-frame, 5 hp, 4 poles, enclosed	Baseline	448
		1	515
		2	560
		3	582
		4	604
		5	627
2	NEMA Design B, T-frame, 30 hp, 4 poles, enclosed	Baseline	923
		1	1,061
		2	1,153

		3	1,199
		4	1,246
		5	1,246
3	NEMA Design B, T-frame, 75 hp, 4 poles, enclosed	Baseline	1,754
		1	2,017
		2	2,193
		3	2,280
		4	2,368
		5	2,456
4	NEMA Design C, T-frame, 5 hp, 4 poles, enclosed	Baseline	515
		1	537
		2	560
		3	582
5	NEMA Design C, T-frame, 50 hp, 4 poles, enclosed	Baseline	1,490
		1	1,555
		2	1,620
		3	1,685
6	Fire pump, 5 hp, 4 poles, enclosed	Baseline	515
		1	560
		2	582
		3	604
		4	627
7	Fire pump, 30 hp, 4 poles, enclosed	Baseline	1,061
		1	1,153
		2	1,199
		3	1,246
		4	1,246
8	Fire pump, 75 hp, 4 poles, enclosed	Baseline	2,017
		1	2,193
		2	2,280
		3	2,368
		4	2,456

For the maintenance costs, DOE did not find data indicating a variation in maintenance costs between a baseline efficiency and a higher efficiency motor. According to Vaughen's, the price of replacing bearings, which is the most common maintenance practice, is the same at all efficiency levels.

8.2.3 Motor Lifetime

For NEMA Designs A, B, and C equipment-class groups, DOE relied on several sources to inform its model of their lifetimes: expert estimates of a motor's average lifetime in years (including repairs) in the industrial sector and average operating hours in all sectors and applications (see chapter 6, Energy Use Characterization).

DOE used the weighted average lifetime estimates across all applications and the application-specific average operating hours in the industry sector to develop average mechanical lifetimes by horsepower range across all sectors (Table 8.2.25).

Table 8.2.25 Motor Mechanical Lifetime by Horsepower Range

Horsepower Range *hp*	Weighted Average Lifetime Across Applications (Industry Sector) *Years*	Mechanical Lifetime Across all Sectors *Hours*
1 – 5	5.0	31,505
6 – 20	5.0	32,850
21 – 50	10.0	64,881
51 – 100	10.0	67,819
101 – 200	15.0	106,424
201 – 500	15.0	108,398

In the LCC, DOE uses a more sophisticated motor lifetime model. This model combines annual operating hours by application and sector with motor mechanical lifetime in hours to estimate the distribution of motor lifetimes in years. This model results in a negative correlation between annual hours of operation and motor lifetime; motors operated many hours per year are likely to be retired sooner than motors that are used for only a few hundred hours per year.

Further, motors with a size less than 50–100 horsepower are typically embedded in other equipment (i.e., “application”) such as pumps or compressors. For each of these motors (less than 75 hp), DOE first determined the lifetime in years by dividing its mechanical lifetime in hours by its annual hours of operation. DOE then compared this lifetime (in years) with the sampled application lifetime (also in years), and assumed that the motor would be retired at the younger of these two ages. For example, a pump motor with a duty factor of 2,500 hours per year may have a mechanical lifetime of 30,000 hours (12 years) and an application lifetime of 10 years. DOE assumed the motor would retire in 10 years, when its application reached the end of its lifetime, even if the motor itself could run for two more years. If the pump motor were to run for 6,000 hours per year, with the same mechanical and application lifetimes, DOE would assume it would retire after 5 years due to motor failure upon reaching its mechanical lifetime of 30,000 hours.

Table 8.2.26 presents the average application lifetimes used in the LCC [14,15,16,17].

Table 8.2.26 Average Application Lifetime

Application	Average Lifetime *Yr*
Air Compressor	15
Fans	15
Pumps	11
Material Handling and Processing	20
Other	15

The DOE's motor lifetime model relies on four distributions: (1) the annual operating hours distribution derived for use in the energy use analysis (see chapter 6); (2) the distribution of motor shipments into six application areas, each with its own distribution of annual hours of operation; (3) a Weibull distribution of mechanical motor lifetimes, expressed in total hours of operation before failure; and (4) a Weibull distribution of application lifetimes, expressed in years. DOE used its estimate of motor mechanical lifetime in hours and application lifetime in years to develop the parameters for the Weibull distributions for all represented units. DOE's Monte Carlo analysis of a motor's LCC selected an application, an appropriate number of hours of operation, a motor mechanical lifetime, and an application lifetime from these distributions in order to calculate the sampled motor's lifetime in years.

The National Impact Analysis (NIA) calculation uses average lifetimes in years by equipment class group, horsepower range, and sector. DOE used the operating hours in order to convert the motor mechanical lifetimes into average lifetimes in years. Results are presented in Table 8.2.27 and Table 8.2.28 by equipment class grouping, horsepower range, and sector. Further, based on literature review,[18,19,20] DOE assumed that the maximum motor lifetime in years is 29 years.[20]

Table 8.2.27 Weighted Average Lifetime for NEMA Design A and B Motors

Horsepower Range ***hp***	**Weighted Average Lifetime** ***Yr***		
	Industrial	**Commercial**	**Agricultural**
1-5	5	15	13
6-20	5	14	13
21-50	10	26	25
51-100	10	26	26
101-200	15	29	29
201-500	15	29	29

Table 8.2.28 Weighted Average Lifetime for NEMA Design C Motors

Horsepower Range ***hp***	**Weighted Average Lifetime** ***Yr***		
	Industrial	**Commercial**	**Agricultural**
1-5	5	14	12
6-20	5	14	15
21-50	10	29	36
51-100	10	25	31
101-200	15	29	29
201-500	15	29	29

DOE further developed Weibull distributions for each of these average lifetimes in years.

For fire pump electric motors, DOE assumed an average lifetime of 29 years and developed a Weibull distribution around this value (both in the LCC and in the NIA).

8.2.3.1 The Weibull Distribution

The Weibull distribution is a probability distribution commonly used to measure failure rates.[b] Its form is similar to an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes over time in a particular fashion. The cumulative Weibull distribution takes the form:

$$P(x) = e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}} \text{ for } x > \theta \text{, and}$$

$$P(x) = 1 \text{ for } x \leq \theta$$

Where:

$P(x)$ = probability that the equipment is still in use at age x,
x = equipment age,
α = scale parameter, which would be the decay length in an exponential distribution,
β = shape parameter, which determines the way in which the failure rate changes through time, and
θ = delay parameter, or location, which allows for a delay before any failures occur.

When $\beta = 1$, the failure rate is constant over time, giving the distribution the form of a cumulative exponential distribution. In the case of mechanical equipment, β commonly is greater than 1, reflecting an increasing failure rate as equipment ages.

8.2.3.2 Mechanical Motor Lifetime and Application Lifetime

DOE's derived Weibull parameters for each representative unit's mechanical lifetime is listed in Table 8.2.29. The Weibull parameters account for a three-year manufacturer warranty period. During this period DOE assumes that no motors fail.

Table 8.2.29 Weibull Parameters for Mechanical Motor Lifetimes

	Representative Unit	Parameters		
		A	β	θ
1	NEMA Design B, T-frame, 5 hp, 4 poles, enclosed	14,179	2.65	18,903
2	NEMA Design B, T-frame, 30 hp, 4 poles, enclosed	51,100	2.65	19,464
3	NEMA Design B, T-frame, 75 hp, 4 poles, enclosed	53,413	2.65	20,346
4	NEMA Design C, T-frame, 5 hp, 4 poles, enclosed	14,179	2.65	18,903
5	NEMA Design C, T-frame, 50 hp, 4 poles, enclosed	51,100	2.65	19,464

[b] For reference on the Weibull distribution, see sections 1.3.6.6.8 and 8.4.1.3 of the *NIST/SEMATECH e-Handbook of Statistical Methods*, <www.itl.nist.gov/div898/handbook/>.

DOE's derived Weibull parameters for motor applications are listed in Table 8.2.30.

Table 8.2.30 Weibull Parameters for Application Lifetime

	Application	Parameters		
		α	B	θ
1	Fan	8.44	2.65	7.50
2	Air Compressor	8.44	2.65	7.50
3	Pump	6.19	2.65	5.50
4	Material Handling and Process	11.25	2.65	10.00
5	Others	8.63	2.65	7.67
6	Fire Pump	16.31	2.65	14.50

In the scope of this life-cycle analysis, DOE combines these two distributions with the appropriately weighted duty factor distribution to select a lifetime for each motor.

Table 8.2.31 summarizes calculated motor lifetimes of sampled motors.

Table 8.2.31 Summary of Sampled Motor Lifetimes

Representative Unit		Median *yr*	Min *yr*	Max *yr*	Average *yr*
1	NEMA Design B, T-frame, 5 hp, 4 poles, enclosed	10.5	2.3	31.3	10.1
2	NEMA Design B, T-frame, 30 hp, 4 poles, enclosed	12.2	2.9	35.4	12.5
3	NEMA Design B, T-frame, 75 hp, 4 poles, enclosed	10.3	2.7	30.6	10.9
4	NEMA Design C, T-frame, 5 hp, 4 poles, enclosed	10.9	2.3	31.8	10.5
5	NEMA Design C, T-frame, 50 hp, 4 poles, enclosed	12.8	2.8	33.1	13.1
6	Fire pump, 5 hp, 4 poles, enclosed	28.8	14.8	51.4	29.1
7	Fire pump, 30 hp, 4 poles, enclosed	28.8	14.8	51.4	29.1
8	Fire pump, 75 hp, 4 poles, enclosed	28.8	14.8	51.4	29.1

8.2.4 Discount Rates

DOE derived the discount rates for the LCC and PBP analysis from estimates of the finance cost of purchasing the considered products. Following financial theory, the finance cost of raising funds to purchase equipment can be interpreted as: (1) the financial cost of any debt incurred to purchase equipment, or (2) the opportunity cost of any equity used to purchase equipment.

Commercial, Industrial, and Agricultural Owners

For motors purchased and used in the industrial, agricultural, and commercial sectors, DOE calculated the discount rate for a distribution of representative equipment owners. This distribution of representative owners is the weighted sum of discount rate distributions for different ownership categories. DOE calculated a distribution of discount rates for owners within each ownership category. The discount rate for an individual owner is the weighted average cost of capital (WACC) where, given the mix of debt and equity for that individual owner, a weighted average of the discount rates for each loan and investment calculated in which the weights are equal to the size of the loan or investment.

DOE estimated the cost of equity using the capital asset pricing model (CAPM).[21] The CAPM assumes that the cost of equity (k_e) for a particular company is proportional to the systematic risk faced by that company, where high risk is associated with a high cost of equity and low risk is associated with a low cost of equity. The systematic risk facing a firm is determined by several variables: the risk coefficient of the firm (β), the expected return on risk-free assets (R_f), and the equity risk premium (*ERP*). The risk coefficient of the firm indicates the risk associated with that firm relative to the price variability in the stock market. The expected return on risk-free assets is defined by the yield on long-term government bonds. The *ERP* represents the difference between the expected stock market return and the risk-free rate. The cost of equity financing is estimated using the following equation, where the variables are defined as above:

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

Where:

k_e = cost of equity,
R_f = expected return on risk-free assets,
β = risk coefficient of the firm, and
ERP = equity risk premium.

Several parameters of the cost of capital equations can vary substantially over time, and therefore the estimates can vary with the time period over which data is selected and the technical details of the data averaging method. For guidance on the time period for selecting and averaging data for key parameters and the averaging method, DOE used Federal Reserve methodologies for calculating these parameters. In its use of the CAPM, the Federal Reserve uses a forty-year period for calculating discount rate averages, utilizes the gross domestic product price deflator for estimating inflation, and considers the best method for determining the risk free rate as one where "the time horizon of the investor is matched with the term of the risk-free security." [22]

Damodaran Online is a widely used source of information about company debt and equity financing for most types of firms.[23] By taking a forty-year geometric average of Damodaran Online data, DOE found for this analysis the following risk free rates for 2009-2011 (Table 8.2.32). DOE also estimated the ERP by calculating the difference between risk free rate and stock market return for the same time period.

Table 8.2.32 Risk-free fate and equity risk premium, 2009-2011

Year	Risk-Free Rate (%)	ERP (%)
2009	6.88	3.07
2010	6.74	3.23
2011	6.61	2.94

The cost of debt financing (k_d) is the interest rate paid on money borrowed by a company. The cost of debt is estimated by adding a risk adjustment factor (R_a) to the risk-free rate. This risk adjustment factor depends on the variability of stock returns represented by standard deviations in stock prices. So for firm *i*, the cost of debt financing is:

$$\boldsymbol{k_{di} = R_f + R_{ai}}$$

Where:

k_d = cost of debt financing for firm, *i*,
R_f = expected return on risk-free assets, and
R_{ai} = risk adjustment factor to risk-free rate for firm, *i*.

DOE estimates the WACC using the following equation:

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

Where:

$WACC$ = weighted average cost of capital,
w_e = proportion of equity financing, and
w_d = proportion of debt financing.

By adjusting for the influence of inflation, DOE estimates the real weighted average cost of capital, or discount rate, for each sector. DOE then aggregates the sectoral real weighted-average costs of capital to estimate the discount rate for each of the three non-residential ownership types in the medium electric motors analysis, weighting each sector's discount rate by the number of companies in the sector.[c]

Table 8.2.33 shows the average WACC values for the three non-residential ownership types in the medium electric motors analysis. While WACC values for any sector may trend higher or lower over substantial periods of time, these values represent a private sector cost of capital that is averaged over major business cycles. Due to limited data availability, DOE applies the discount rate estimated for the industrial sector to the agricultural sector.

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[c] Giving equal weight to each industry, rather than weighting by number of companies leads to similar estimate of discount rates; the mean industrial / agricultural discount rate is estimated to be 6.00% and the mean commercial discount rate is estimated to be 5.86%.

Table 8.2.33 Weighted Average Cost of Capital for Sectors that Purchase Medium Electric Motors

Sector	Real Weighted Average Cost of Capital %
Industrial	5.82
Agricultural	5.82
Commercial	5.66

8.2.5 Effective Date and Compliance Date of Standard

The effective date of an energy conservation standard is essentially the official date that the text of the final rule becomes a regulation in the Code of Federal Regulations. The compliance date is when compliance with a standard is required. Any amended standard for electric motors "shall apply to electric motors manufactured on or after a date which is five years after the effective date of the standards date such rule is published." (42 U.S.C. 6313(b)(3)) In this case, the statutory effective date was December 19, 2010, and the compliance date of any new energy conservation standard for electric motors would be December 19, 2015. DOE calculated the LCC and PBP for all end-users as if each would purchase a new piece of equipment in the year that compliance is required.

8.2.6 Equipment Energy Efficiency in the Base Case

For purposes of conducting the LCC analysis, DOE analyzed efficiency levels relative to a base case (*i.e.*, the case without new energy efficiency standards). This requires an estimate of the distribution of equipment efficiencies in the base case (*i.e.*, what consumers would have purchased in the year 2015 in the absence of new standards). DOE refers to this distribution of equipment energy efficiencies as the base-case efficiency distribution.

DOE used six major manufacturer and one distributor's catalog data to develop the base-case efficiency distributions using the number of models (in all representative units) meeting the requirements of each efficiency level. The distribution is estimated separately for each representative unit.

Table 8.2.34 shows the energy efficiency distribution for base cases for all representative units. Using the base case efficiency distribution, DOE assigned a baseline efficiency to each motor unit. If a unit is assigned a baseline efficiency that is greater than or equal to the efficiency of the standard level under consideration, the LCC calculation shows that this unit would not be affected by that standard level.

Table 8.2.34 Base Case Energy Efficiency Distribution for All Representative Units

Unit #1: NEMA Design B, T-Frame, 5 hp, 4 poles, Enclosed			
Level		FL* Nominal Efficiency	Share
0	Minimum Commercially Available	82.5%	0.06
1	EPACT 1992	87.5%	0.38
2	NEMA Premium	89.5%	0.44
3	Maximum Commercially Available	90.2%	0.08
4	Incremental	91.0%	0.03
5	Maximum Technology	91.7%	0.01
Unit #2: NEMA Design B, T-Frame, 30 hp, 4 poles, Enclosed			
Level		FL Nominal Efficiency	Share
0	Minimum Commercially Available	89.5%	0.05
1	EPACT 1992	92.4%	0.30
2	NEMA Premium	93.6%	0.48
3	Maximum Commercially Available	94.1%	0.09
4	Incremental	94.5%	0.08
5	Maximum Technology	94.5%	0.00
Unit #3: NEMA Design B, T-Frame, 75 hp, 4 poles, Enclosed			
Level		FL Nominal Efficiency	Share
0	Minimum Commercially Available	93.0%	0.05
1	EPACT 1992	94.1%	0.29
2	NEMA Premium	95.4%	0.48
3	Maximum Commercially Available	95.8%	0.10
4	Incremental	96.2%	0.05
5	Maximum Technology	96.5%	0.02
Unit #4: NEMA Design C, T-Frame, 5 hp, 4 poles, Enclosed			
Level		FL Nominal Efficiency	Share
0	EPACT 1992	87.5%	0.92
1	NEMA Premium	89.5%	0.08
2	Incremental	90.2%	0.00
3	Maximum Technology	91.0%	0.00
Unit #5: NEMA Design C, T-Frame, 50 hp, 4 poles, Enclosed			
Level		FL Nominal Efficiency	Share
0	EPACT 1992	93.0%	0.73
1	Incremental	94.1%	0.27
2	NEMA Premium	94.5%	0.00
3	Maximum Technology	95.0%	0.00
Unit #6: Fire Pump, 5 h, 4 poles, Enclosed			
Level		FL Nominal Efficiency	Share
0	EPACT 1992	87.5%	0.95
1	NEMA Premium	89.5%	0.05
2	Maximum Commercially Available	90.2%	0.00
3	Incremental	91.0%	0.00
4	Maximum Technology	91.7%	0.00
Unit #7: Fire Pump, 30 hp, 4 poles, Enclosed			
Level		FL Nominal Efficiency	Share
0	EPACT 1992	92.4%	0.82
1	NEMA Premium	93.6%	0.06
2	Maximum Commercially Available	94.1%	0.13
3	Incremental	94.5%	0.00
4	Maximum Technology	94.5%	0.00

Unit #8: Fire Pump, 75 hp, 4 poles, Enclosed			
Level		FL Nominal Efficiency	Share
0	EPACT 1992	94.1%	0.81
1	NEMA Premium	95.4%	0.02
2	Maximum Commercially Available	95.8%	0.17
3	Incremental	96.2%	0.00
4	Maximum Technology	96.5%	0.00

*FL = Full Load

8.3 PAYBACK PERIOD INPUTS

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

The equation for PBP is:

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

Where:

ΔIC = change, generally an increase in the total installed cost between the more efficient standard level and the baseline design, and
ΔOC = change, generally a decrease in annual operating expenses.

A PBP is expressed in years. A PBP that is greater than the life of the product indicates that the increased total installed cost is not recovered in reduced operating expenses.

The data inputs to PBP are the total installed cost of the equipment to the purchaser for each efficiency level and the annual (first-year) operating expenditures for each standard 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 as described in section 8.2, except that lifetime, energy price trends, and discount rates are not required. Because the PBP is a “simple” payback, the required energy price is only for the year in which compliance with a new standard is required—in this case, the year 2015. The energy price DOE used in the PBP calculation was the price projected for that year.

8.4 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS FOR REPRESENTATIVE UNITS

This section presents the LCC and PBP results for the representative units analyzed. As discussed in section 8.1.1, DOE's approach for conducting the LCC analysis relied on developing samples of customers for each representative unit. DOE also characterized the uncertainty of many of the inputs to the analysis with probability distributions. DOE used a Monte Carlo simulation technique to perform the LCC calculations on the customers in the sample. For each set of sample customers using motors in each representative unit, DOE calculated the average LCC and LCC savings and the median and average PBP for each of the standard levels.

In the subsections below, DOE presents figures showing the distribution of LCCs in the base case for each representative unit. Also presented below for a specific standard level are figures showing the distribution of LCC impacts and the distribution of PBPs. The figures are presented as frequency charts that show the distribution of LCCs, LCC impacts, and PBPs with their corresponding probabilities of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples. The LCC and PBP calculations were performed 10,000 times by sampling from the probability distributions that DOE developed to characterize many of the inputs.

Based on the Monte Carlo simulations that DOE performed, for each efficiency level, DOE calculated the share of motor users with a net LCC benefit and with a net LCC cost. To illustrate the range of LCC and PBP impacts among the motor end-users, the sections below present figures that provide such information for each representative unit.

8.4.1 Representative Unit 1, NEMA Design B, 5 Horsepower, 4 poles, Enclosed Motor

Figure 8.4.1 is an example of a frequency chart showing the distribution of LCC savings for representative unit 1, at candidate standard level (CSL) 3. The efficiency level of CSL 3 is the maximum commercially available level for representative unit 1 motors. In the figure, a text box next to a vertical line at that value on the x-axis shows the mean change in LCC (a net benefit of approximately $45 in this example Monte Carlo run).

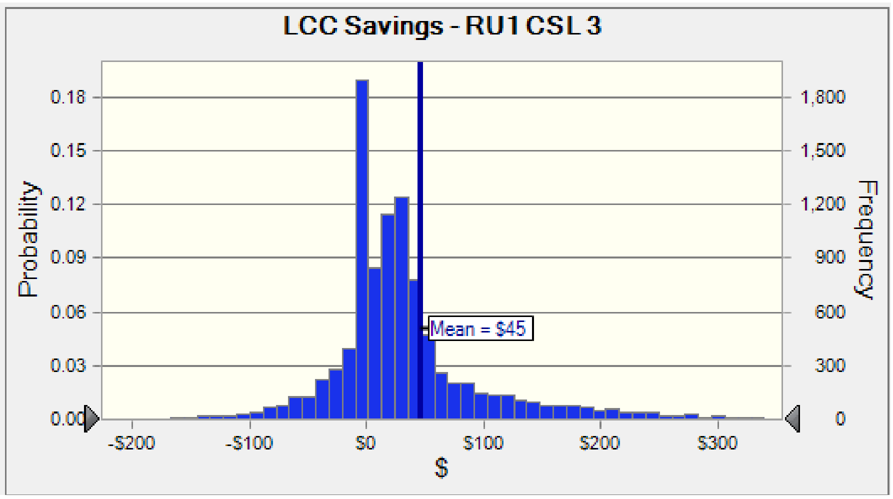

Figure 8.4.1 Representative Unit 1: Distribution of Life-Cycle Cost Savings for CSL 2

Figure 8.4.2 is an example of a frequency chart showing the distribution of PBPs for the efficiency level corresponding to CSL 3 for the representative unit 1. Because many motors operate for very few hours per year and because the operating cost savings is very small compared to the increase in first cost, there are a significant number of motors that may have extremely long PBPs. The distribution in the figure illustrates that most motors have a payback of less than 30 years, but the mean value of the distribution payback is large (59.0 years) because of the small, but significant number of motors with PBPs longer than 60 years. Because of the skewed distribution in PBPs, DOE also considers the PBP of the typical customer, or the median of the distribution, which is 4.7 years for Figure 8.4.2.

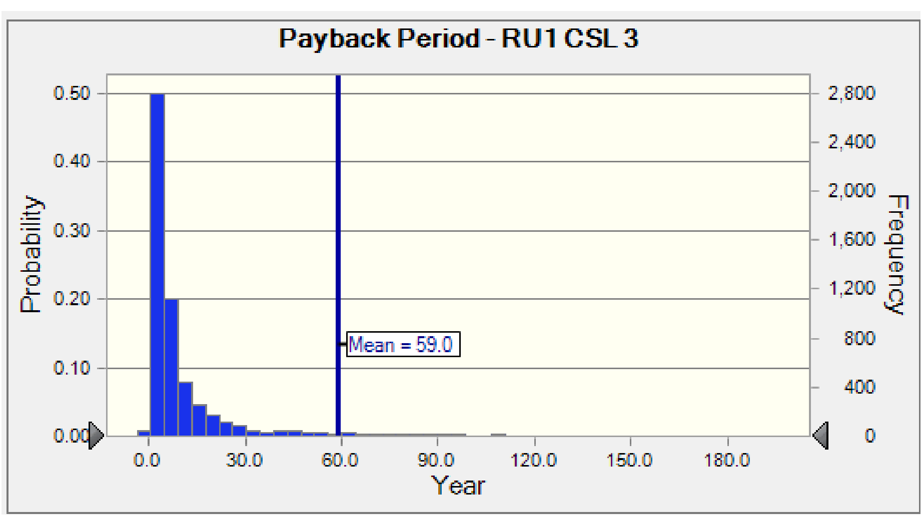

Figure 8.4.2 Representative Unit 1: Distribution of Payback Periods for CSL 2.

The distribution of PBP for other representative units associated with other efficiency levels are illustrated in Appendix 8-B.

Table 8.4.1 summarizes the LCC and PBP results for the representative unit 1 based on a run of 10,000 Monte Carlo samples. The most rigorous CSL that provides positive average LCC savings is CSL 3. DOE estimates that 67.8 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL. At this CSL the increase in average total installed cost (relative to the base case) is $81, or 13.9 percent, while operating costs decrease by $46, or 4.6 percent.

Table 8.4.1 Life-Cycle Cost and Payback Period Results for Representative Unit 1: NEMA Design B, T-Frame, 5 horsepower, Four Poles, Enclosed Motor

Energy Efficiency Level	Efficiency *%*	Life-Cycle Cost				Life-Cycle Cost Savings			Payback Period *years*	
		Average Installed Price *$*	Average Energy Use *kWh/yr*	Average Annual Operating Cost *$*	Average Life-Cycle Cost *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Average	Median
0	82.5	584	10,448	1,006	5,926					
1	87.5	588	9,869	969	5,649	16	0.1	5.8	0.4	0.1
2	89.5	651	9,691	963	5,631	25	18.9	26.4	33.7	5.1
3	90.2	665	9,616	960	5,608	45	20.5	67.8	59.0	4.7
4	91.0	909	9,567	960	5,831	-169	89.3	6.5	361.4	28.2
5	91.7	998	9,487	958	5,883	-220	93.3	5.4	162.7	26.9

8.4.2 Representative Unit 2, NEMA Design B, 30 Horsepower, 4 poles, Enclosed Motor

Figure 8.4.3 is an example of a frequency chart showing the distribution of LCC impacts for the case of CSL 3 for the representative unit 2, that is, an energy efficiency of 94.1 percent for a NEMA Design B, T-frame, 30 horsepower, 4-pole, enclosed electric motor. The net benefit of LCC is $511 in this Monte Carlo run.

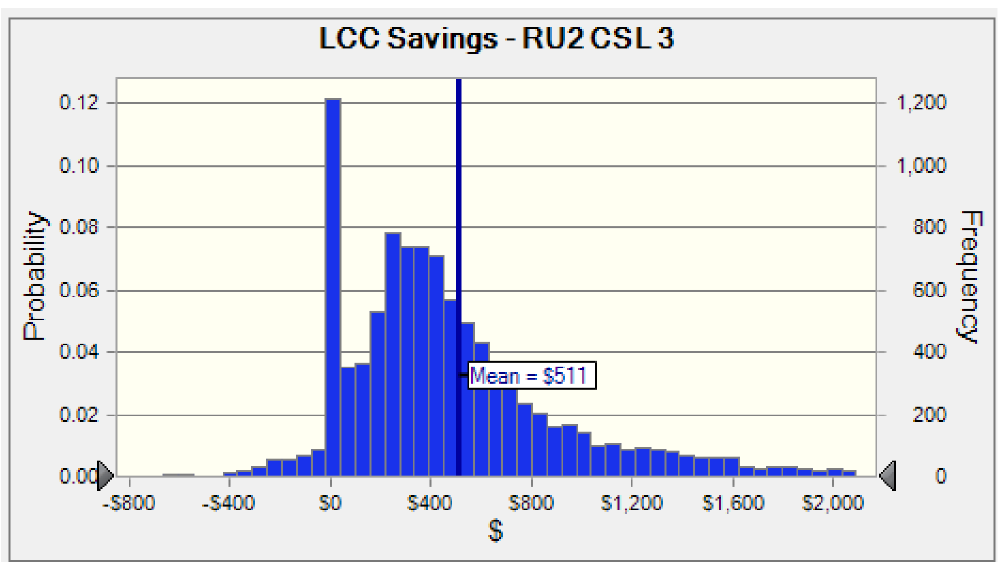

Figure 8.4.3 Representative Unit 2: Distribution of Life-Cycle Cost Savings for CSL 2

Table 8.4.2 summarizes the LCC and PBP results for representative unit 2 based on a run of 10,000 Monte Carlo samples. The most rigorous CSL that provides positive average LCC savings is CSL 3. DOE estimates that 86.6 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL. At this CSL the increase in average total installed cost (relative to the base case) is $718, or 45.7 percent, while operating costs decrease by $234, or 4.3 percent.

Table 8.4.2 Life-Cycle Cost and Payback Period Results for Representative Unit 2: NEMA Design B, T-Frame, 30 hp, Four Poles, Enclosed Motor

Energy Efficiency Level	Efficiency *%*	Life-Cycle Cost				Life-Cycle Cost Savings			Payback Period *years*	
		Average Installed Price *$*	Average Energy Use *kWh/yr*	Average Annual Operating Cost *$*	Average Life-Cycle Cost *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Average	Median
0	89.5	1,570	57,642	5,489	44,182					
1	92.4	1,986	55,912	5,358	43,376	45	0.6	4.9	11.6	3.5
2	93.6	2,277	55,021	5,295	43,035	177	5.7	32.9	14.6	5.3
3	94.1	2,288	54,492	5,255	42,666	511	4.0	86.6	6.0	0.7
4	94.5	3,468	54,326	5,249	43,735	-558	87.1	12.9	107.6	23.8

8.4.3 Representative Unit 3, NEMA Design B, 75 Horsepower, 4 poles, Enclosed Motor

Figure 8.4.4 is an example of a frequency chart showing the distribution of LCC savings for the case of CSL 3 for the representative unit 3. The LCC net benefit is $597 in this Monte Carlo run. DOE has published a frequency chart like the one shown in Figure 8.4.4 for every efficiency level in Appendix 8-B to this chapter.

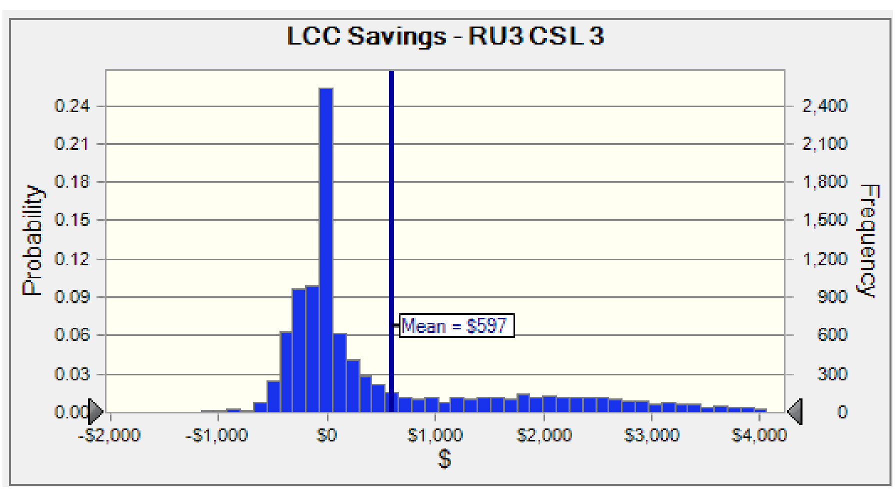

Figure 8.4.4 Representative Unit 3: Distribution of Life-Cycle Cost Savings for CSL 2

Table 8.4.3 summarizes the LCC and PBP results for representative unit 3 based on a run of 10,000 Monte Carlo samples. The most rigorous CSL that provides positive average LCC savings is CSL 3. DOE estimates that 47.5 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL. At this CSL the increase in average total installed cost (relative to the base case) is $1,313, or 37.9 percent, while operating costs decrease by $481, or 2.8 percent.

Table 8.4.3 Life-Cycle Cost and Payback Period Results for Representative Unit 3: NEMA Design B, T-Frame, 75 hp, Four Poles, Enclosed Motor

Energy Efficiency Level	**Efficiency** *%*	**Life-Cycle Cost**				**Life-Cycle Cost Savings**			**Payback Period** *years*	
		Average Installed Price *$*	**Average Energy Use** *kWh/yr*	**Average Annual Operating Cost** *$*	**Average Life-Cycle Cost** *$*	**Average Savings** *$*	**Customers with Net Cost** *%*	**Customers with Net Benefit** *%*	**Average**	**Median**
0	93.0	3,463	204,834	17,168	124,170					
1	94.1	3,831	202,540	17,033	123,348	40	0.8	4.5	24.3	2.9
2	95.4	4,296	198,496	16,733	121,510	663	1.4	32.9	6.6	1.5
3	95.8	4,776	197,697	16,687	121,590	597	35.1	47.5	38.3	6.5
4	96.2	6,044	197,194	16,661	122,598	-340	66.9	25.9	162.7	15.5
5	96.5	6,640	196,604	16,631	122,905	-639	73.6	23.7	136.2	16.0

8.4.4 Representative Unit 4, NEMA Design C, 5 Horsepower, 4 poles, Enclosed Motor

Figure 8.4.5 is an example of a frequency chart showing the distribution of LCC savings for the case of CSL 2 for the representative unit 4. The LCC net benefit is -$203 in this Monte Carlo run.

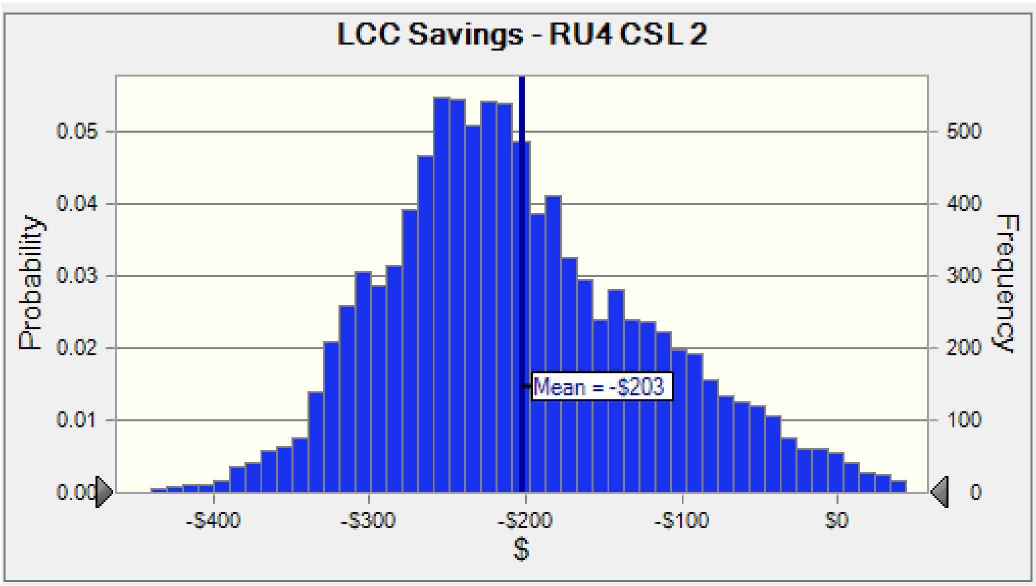

Figure 8.4.5 Representative Unit 4: Distribution of Life-Cycle Cost Savings for CSL 2

Table 8.4.4 summarizes the LCC and PBP results for the representative unit 4 based on a run of 10,000 Monte Carlo samples. The most rigorous CSL that provides positive average LCC savings is CSL 1. DOE estimates that 59.9 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL. At this CSL the increase in average total installed cost (relative to the base case) is $44, or 7.5 percent, while operating costs decrease by $10, or 1.0 percent.

Table 8.4.4 Life-Cycle Cost and Payback Period Results for Representative Unit 4: NEMA Design C, T-Frame, 5 hp, Four Poles, Enclosed Motor

Energy Efficiency Level	Efficiency *%*	Life-Cycle Cost				Life-Cycle Cost Savings			Payback Period *years*	
		Average Installed Price *$*	Average Energy Use *kWh/yr*	Average Annual Operating Cost *$*	Average Life-Cycle Cost *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Average	Median
0	87.5	583	9,987	984	5,807					
1	89.5	627	9,808	974	5,771	34	32.3	59.9	29.7	4.6
2	90.2	903	9,738	971	6,007	-203	97.8	2.2	95.6	25.0
3	91.0	961	9,630	966	6,011	-207	95.6	4.4	122.7	20.2

8.4.5 Representative Unit 5, NEMA Design C, 50 Horsepower, 4 poles, Enclosed Motor

Figure 8.4.6 is an example of a frequency chart showing the distribution of LCC savings for the case of CSL 2 for the representative unit 5. The LCC net benefit is $5 in this Monte Carlo run.

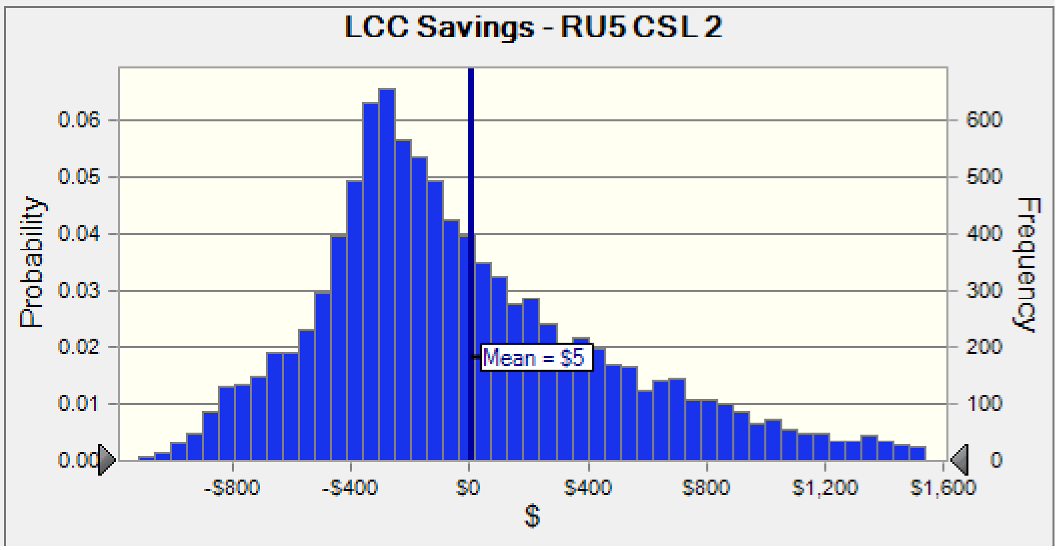

Figure 8.4.6 Representative Unit 5: Distribution of Life-Cycle Cost Savings for CSL 2

Table 8.4.5 summarizes the LCC and PBP results for representative unit 5 based on a run of 10,000 Monte Carlo samples. The most rigorous CSL that provides positive average LCC savings is CSL 3. DOE estimates that 57.8 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL. At this CSL the increase in average total installed cost (relative to the base case) is $1,164, or 41.8 percent, while operating costs decrease by $150, or 1.8 percent.

Table 8.4.5 Life-Cycle Cost and Payback Period results for Representative Unit 5: NEMA Design C, T-Frame, 50 hp, Four Pole, Enclosed Motor

Energy Efficiency Level	Efficiency *%*	Life-Cycle Cost				Life-Cycle Cost Savings			Payback Period *years*	
		Average Installed Price *$*	Average Energy Use *kWh/yr*	Average Annual Operating Cost *$*	Average Life-Cycle Cost *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Average	Median
0	93.0	2,786	89,523	8,459	69,419					
1	94.1	3,173	88,507	8,383	69,098	236	18.3	55.6	38.8	5.9
2	94.5	3,673	88,119	8,360	69,329	5	59.6	40.4	53.3	12.7
3	95.0	3,950	87,444	8,309	69,104	229	42.3	57.8	25.2	9.8

8.4.6 Representative Unit 6, Fire Pump, 5 Horsepower, 4 poles, Enclosed Motor

Figure 8.4.7 is an example of a frequency chart showing the distribution of LCC savings for the case of CSL 2 for representative unit 6. The LCC net benefit is -$70 in this Monte Carlo run.

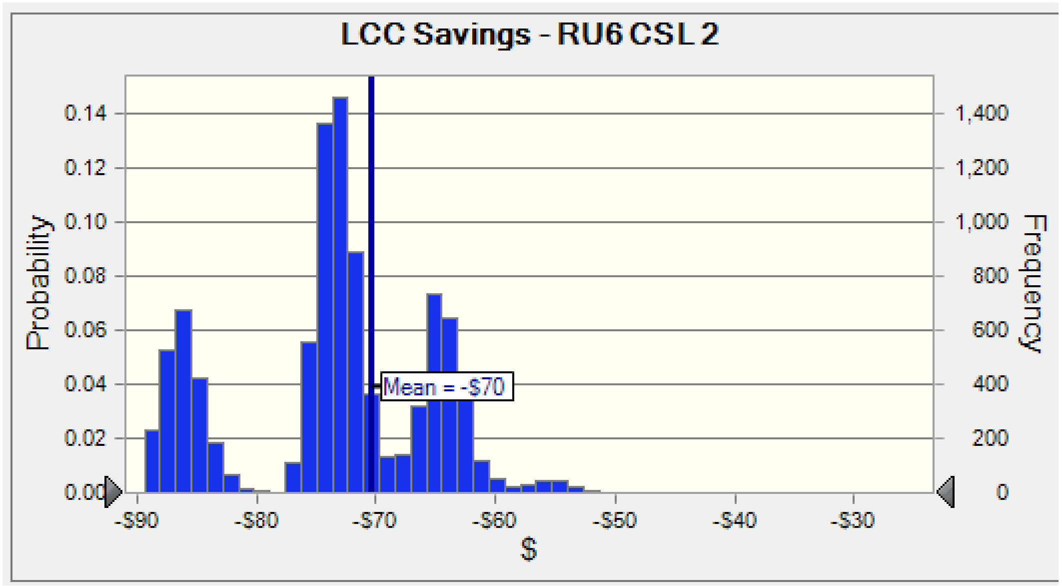

Figure 8.4.7 Representative Unit 6: Distribution of Life-Cycle Cost Savings for CSL 2

Table 8.4.6 summarizes the LCC and PBP results for Unit 6 motors based on a run of 10,000 Monte Carlo samples. All CSLs lead to negative average LCC savings.

Table 8.4.6 Life-Cycle Cost and Payback Period Results for Representative Unit 6: Fire Pump, NEMA Design B, T-Frame, 5 hp, Four Poles, Enclosed Motor

Energy Efficiency Level	Efficiency %	Life-Cycle Cost				Life-Cycle Cost Savings			Payback Period *years*	
		Average Installed Price *$*	Average Energy Use *kWh/yr*	Average Annual Operating Cost *$*	Average Life-Cycle Cost *$*	Average Savings *$*	Customers with			
							Net Cost *%*	Net Benefit *%*	Average	Median
0	87.5	588	19.6	106	632					
1	89.5	651	19.2	115	697	-62	95.1	0.0	NA	NA
2	90.2	665	19.1	119	706	-70	99.9	0.1	NA	NA
3	91.0	909	19.0	124	949	-314	100.0	0.0	NA	NA
4	91.7	998	18.8	128	1,038	-403	100.0	0.0	NA	NA

8.4.7 Representative Unit 7, Fire Pump, 30 Horsepower, 4 poles, Enclosed Motor

Figure 8.4.8 is an example of a frequency chart showing the distribution of LCC savings for the case of CSL 2 for the representative unit 7. The LCC net benefit is -$207 in this Monte Carlo run.

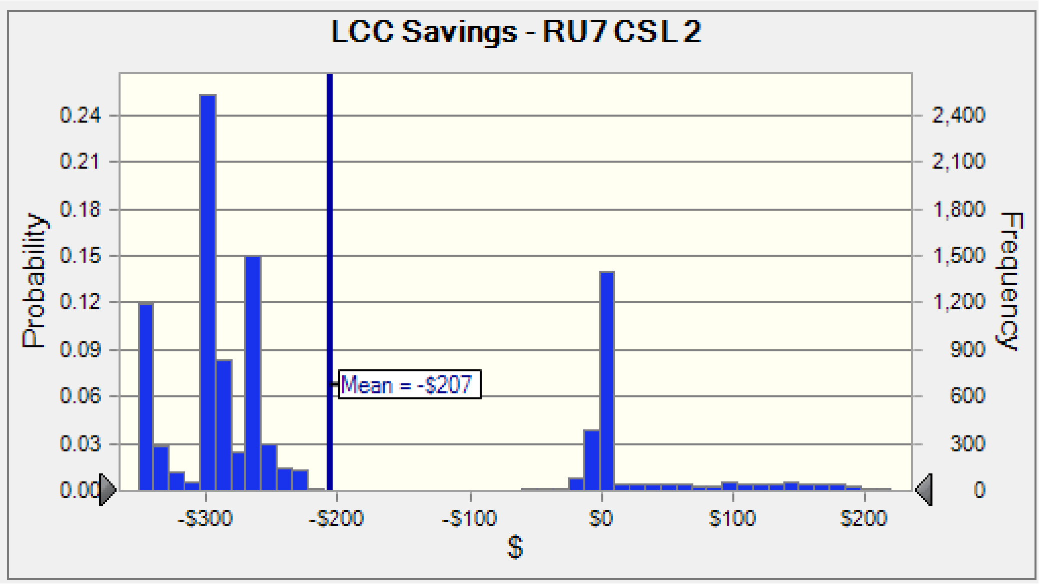

Figure 8.4.8 Representative Unit 7: Distribution of Life-Cycle Cost Savings for CSL 2

Table 8.4.7 summarizes the LCC and PBP results for representative unit 7 based on a run of 10,000 Monte Carlo samples. All CSLs lead to negative average LCC savings.

Table 8.4.7 Life-Cycle Cost and Payback Period Results for Representative Unit 7: Fire Pump, NEMA Design B, T-Frame, 30 hp, Four Poles, Enclosed Motor

Energy Efficiency Level	Efficiency *%*	Life-Cycle Cost				Life-Cycle Cost Savings			Payback Period *years*	
		Average Installed Price *$*	Average Energy Use *kWh/yr*	Average Annual Operating Cost *$*	Average Life-Cycle Cost *$*	Average Savings *$*	Customers with			
							Net Cost *%*	Net Benefit *%*	Average	Median
0	92.4	1,986	1,601	347	3,869					
1	93.6	2,277	1,577	363	4,131	-213	78.8	2.5	1,579	104.9
2	94.1	2,288	1,562	371	4,124	-207	78.7	8.1	923	79.2
3	94.5	3,468	1,558	380	5,295	-1,378	100.0	0.0	3,157	433.6
4	94.5	3,468	1,558	380	5,295	-1,378	100.0	0.0	3,157	433.6

8.4.8 Representative Unit 8, Fire Pump, 75 Horsepower, 4 poles, Enclosed Motor

Figure 8.4.9 is an example of a frequency chart showing the distribution of LCC savings for the case of CSL 2 for the representative unit 8. The LCC net benefit is $1,193 in this Monte Carlo run.

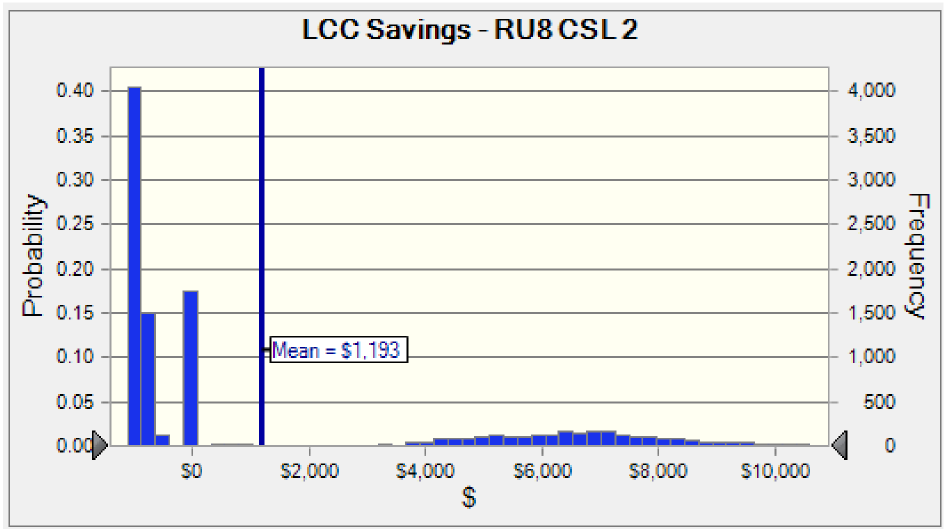

Figure 8.4.9 Representative Unit 8: Distribution of Life-Cycle Cost Savings for CSL 2

Table 8.4.8 summarizes the LCC and PBP results for the representative unit 8 based on a run of 10,000 Monte Carlo samples. The most rigorous CSL that provides positive average LCC savings is CSL 3. DOE estimates that 27.0 percent of end-users would experience a net benefit (i.e., LCC decrease) at this CSL. At this CSL the increase in average total installed cost (relative to the base case) is $2,213, or 57.8 percent, while operating costs decrease by $126, or 1.6 percent.

Table 8.4.8 Life-Cycle Cost and Payback Period Results for Representative Unit 8: Fire Pump, NEMA Design B, T-Frame, 75 hp, Four Poles, Enclosed Motor

Energy Efficiency Level	Efficiency *%*	Life-Cycle Cost				Life-Cycle Cost Savings			Payback Period *years*	
		Average Installed Price *$*	Average Energy Use *kWh/yr*	Average Annual Operating Cost *$*	Average Life-Cycle Cost *$*	Average Savings *$*	Customers with Net Cost *%*	Customers with Net Benefit *%*	Average	Median
0	94.1	3,831	97,791	8,050	110,032					
1	95.4	4,296	95,934	7,937	108,445	1,274	55.4	25.3	1.1	1.1
2	95.8	4,776	95,554	7,927	108,544	1,193	56.7	26.0	2.1	1.9
3	96.2	6,044	95,313	7,924	109,522	215	73.0	27.0	25.3	4.5
4	96.5	6,640	95,033	7,920	109,826	-89	72.0	28.0	10.5	5.3

8.5 LIFE-CYCLE COST SENSITIVITY CALCULATIONS

DOE developed a number of sensitivity analyses in order to analyze the particular impacts of many inputs to its LCC analysis. These sensitivity analyses include lower and higher retail price discounts, and two alternative energy price trend scenarios. Table 8.5.1 displays the user choices and associated values for each sensitivity parameter analyzed.

Table 8.5.1 Life-Cycle Cost Sensitivity Case Parameters and Values

Parameter	Choices	Typical Value
Energy Price Trend	Default High Value Low Value	AEO 2011 Reference Case AEO 2011 High Case AEO 2011 Low Case
Retail Price Discount	Default High Discount Medium Discount Low Discount	1 0.7 0.5 0.3

Table 8.5.2 compares the average LCC savings using the default value for energy price trends with the LCC savings using high and low sensitivity values for representative units 2, 5, and 7. As expected, DOE observed larger savings with higher energy prices and smaller savings with lower energy prices.

Table 8.5.2 Life –Cycle Cost Results for Energy Price Trend Sensitivity Cases

Representative Unit 2				
Energy Efficiency Level	Efficiency %	Average LCC Savings $		
		Default Value	High Value	Low Value
0	89.5			
1	92.4	45	47	43
2	93.6	177	187	168
3	94.1	511	532	492
4	94.5	-558	-533	-580
5	94.5	-558	-533	-580
Representative Unit 5				
Energy Efficiency Level	Efficiency %	Average LCC Savings $		
		Default Value	High Value	Low Value
0	93.0			
1	94.1	236	253	221
2	94.5	5	31	-18
3	95.0	229	272	192
Representative Unit 7				

Energy Efficiency Level	Efficiency %	Average LCC Savings $		
		Default Value	High Value	Low Value
0	92.4			
1	93.6	-213	-212	-214
2	94.1	-207	-205	-209
3	94.5	-1,378	-1,376	-1,380
4	94.5	-1,378	-1,376	-1,380

Table 8.5.3 shows an example of retail price discount sensitivity analyses for representative units 2, 5, and 7. The default case does not include any discounts, whereas the other cases incorporate different discounts. The sensitivity results reflect that the higher the discount used, the greater the savings that are achieved.

Table 8.5.3 Life –Cycle Cost Results for Retail Price Discount Sensitivity Cases

Representative Unit 2					
Energy Efficiency Level	Efficiency %	Average LCC Savings $			
		Default Value	Low	Medium	High
0	89.5				
1	92.4	45	51	55	59
2	93.6	177	209	230	251
3	94.1	511	547	571	595
4	94.5	-558	-193	51	294
5	94.5	-558	-193	51	294
Representative Unit 5					
Energy Efficiency Level	Efficiency %	Average LCC Savings $			
		Default Value	Low	Medium	High
0	93.0				
1	94.1	236	307	354	401
2	94.5	5	223	368	513
3	95.0	229	526	724	922
Representative Unit 7					

Energy Efficiency Level	Efficiency %	Average LCC Savings $			
		Default Value	Low	Medium	High
0	92.4				
1	93.6	-213	-159	-122	-86
2	94.1	-207	-149	-109	-70
3	94.5	-1,378	-990	-732	-473
4	94.5	-1,378	-990	-732	-473

DOE collected the results of each sensitivity analysis, applied individually, in Appendix 8-C. The DOE's LCC analysis and PBP spreadsheet tool is available for download via the Internet[d] and allows the user to examine the results for the sensitivity scenario of their choice.

8.6 REBUTTABLE PAYBACK PERIOD

A more energy efficient motor will usually cost more to buy than a motor of standard energy efficiency. However, the more efficient motor will usually cost less to operate due to reductions in operating costs (*i.e.*, lower energy bills). The PBP is the time (usually expressed in years) it takes to recover the additional installed cost of the more efficient motor through energy cost savings. The Energy Policy and Conservation Act (EPCA) provides a rebuttable presumption that, in essence, an energy conservation standard is economically justified if the increased purchase cost for a product that meets the standard is less than three times the value of the first-year energy savings resulting from the standard. However, DOE routinely conducts a full economic analysis that considers the full range of impacts, including those to the customer, manufacturer, nation, and environment, as required under 42 U.S.C. 6295(o)(2)(B)(i) and 42 U.S.C. 6316(e)(1). The results of this analysis serve as the basis for DOE to evaluate definitively the economic justification for a potential standard level (thereby supporting or rebutting the results of any preliminary determination of economic justification).

The results of DOE's rebuttable PBP calculations are shown in Table 8.6.1 below.

[d] See links from this web site: http://www1.eere.energy.gov/buildings/appliance_standards/commercial/small_electric_motors.html

Table 8.6.1 Rebuttable Presumption Payback for All Representative Units

Representative Unit		Payback Period *years*				
		CSL 1	**CSL 2**	**CSL 3**	**CSL 4**	**CSL 5**
1	NEMA Design B, T-frame, 5 hp, 4 poles, enclosed	0.0	0.5	0.6	2.2	2.7
2	NEMA Design B, T-frame, 30 hp, 4 poles, enclosed	0.8	1.1	1.0	2.7	2.7
3	NEMA Design B, T-frame, 75 hp, 4 poles, enclosed	1.1	1.2	1.6	2.8	3.2
4	NEMA Design C, T-frame, 5 hp, 4 poles, enclosed	1.3	7.0	6.5	-	-
5	NEMA Design C, T-frame, 50 hp, 4 poles, enclosed	2.8	4.8	4.7	-	-
6	Fire pump, 5 hp, 4 poles, enclosed	1,013	926	3,013	3,231	-
7	Fire pump, 30 hp, 4 poles, enclosed	99	73	290	290	-
8	Fire pump, 75 hp, 4 poles, enclosed	2.8	4.3	8.2	9.1	-

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