

CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSES

8.1 INTRODUCTION

This chapter describes the analysis the U.S. Department of Energy (DOE) conducts to evaluate the economic impacts on individual consumers of possible energy conservation standards for general service fluorescent lamps (GSFL) and incandescent reflector lamps (IRL). New standards usually decrease operating costs and increase purchase costs for consumers. This chapter describes the three metrics used in this analysis to determine the impact of standards on individual consumers:

Life-cycle cost (LCC) is the total (discounted) consumer cost over the analysis period including purchase price, operating costs (including energy expenditures), and installation costs.

Payback period (PBP) is the number of years it takes a customer to recover the generally higher purchase price of a more energy-efficient product through the operating cost savings of using the more energy-efficient product. The PBP is calculated as the change in first cost divided by the change in operating costs in the first year.

Rebuttable payback period is a special case in which the PBP is calculated based on laboratory conditions, specifically DOE test procedure inputs. DOE calculates the aforementioned LCC and PBP using a range of inputs, which are designed to reflect actual conditions.

Sections 8.2 and 8.3 discuss inputs to the LCC and PBP, respectively. Section 8.4 discusses the different purchasing events DOE analyzes, which affect consumer economics. Section 8.5 presents the results for the LCC and PBP. Key variables and calculations are presented for each metric. DOE performs the calculations discussed here using a series of Microsoft Excel[®] spreadsheets developed for this rulemaking. Stakeholders are invited to download and examine the spreadsheets, which are available at http://www.eere.energy.gov/buildings/appliance_standards/residential/incandescent_lamps.html. Appendix 8A presents details and instructions for using the spreadsheets. Appendix 8B presents sensitivity results as well as results of the Monte Carlo model.

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

Recognizing that several inputs to the LCC and PBP analysis are either variable or uncertain, DOE incorporates Monte Carlo simulation and probability distributions into its LCC and PBP model. Appendix 8B contains a detailed set of results using Monte Carlo simulation. DOE incorporates both Monte Carlo simulation and probability distributions by using Microsoft Excel spreadsheets combined with Crystal Ball[®], a commercially available add-in program.

The relationship between increasing selling price and increasing efficacy is the predominant influence on the LCC and PBP results. However, other factors related to the characteristics of the consumer using the products also affect the results. Based on the

geographic region, sector, and application in which a consumer uses the lamps, factors such as energy prices, sales tax, and energy usage can vary. By using the Monte Carlo simulation and separate sensitivity runs, DOE accounts for this variability.

For the LCC and PBP analyses, DOE considers variability in the discount rate. DOE also models variability in operating hours by sector, lamp type, and building applications. By developing samples by building type, DOE can perform the LCC and PBP calculations and account for the variability in operating hours, electricity price, and sales tax among a variety of buildings. DOE uses the Energy Information Administration's (EIA) 2001 Residential Energy Consumption Survey (RECS), 2003 Commercial Buildings Energy Consumption Survey (CBECS), and 2002 Manufacturing Energy Consumption Survey (MECS) to develop samples by building type, as well as U.S. Lighting Market Characterization: Volume I (LMC) to develop the operating hour characteristics by application in those buildings. The LCC and PBP spreadsheets present the results of the analysis as average values, relative to the baseline conditions. (Appendix 8B presents more information on the distribution of results from the LCC and PBP analysis, including the average and median PBP values and the percentages of trials which result in positive or negative LCCs).

In the LCC and PBP analyses, DOE considers multiple pathways to energy savings. Generally, when moving up in lamp efficacy consumers choose whether to stay at the same rated lamp wattage and have more light output, or move to a lower wattage and have the same or roughly equivalent light output as the baseline lamp and lamp-and-ballast system. While consumers clearly would have other choices in addition to those presented in the LCC, DOE considers only energy-saving lamp designs and lamp-and-ballast designs in the LCC. Other choices, such as substituting a lamp that is outside the scope of this rulemaking (e.g., exempted 65 Watt bulged reflector (BR) IRL) or substituting a lamp with a higher efficacy lamp that does not save energy are addressed in the national impact analysis (national impacts analysis (NIA); Chapter 10).

For GSFL, DOE considers various scenarios that prompt consumers to buy a lamp or lamp-and-ballast system in the base versus standards cases. Specifically, the "event" that prompts the purchase of a new lamp (e.g., a lamp failure or a ballast failure) will influence the cost-effectiveness of the consumer purchase decision. For example, depending on the efficacy level (EL), a consumer may or may not have to purchase a new ballast to install a more efficacious lamp. Whether the consumer would have replaced the ballast absent standards affects the economics of the substitution. DOE, therefore, bases the LCC and PBP analyses around "lamp purchasing events." For IRL where no ballast is involved, DOE simply analyzes lamp failure or new construction scenarios. Section 8.4 discusses the lamp purchasing events for GSFL in more detail. The LCC and PBP analyses spreadsheet reports results per purchasing event.

The time period used for the LCC and PBP analyses in this rulemaking is the service life of the longest baseline lamp, or a multiple thereof. By using this analysis period, LCC results are more easily compared and contrasted for different ELs. However, to account for any remaining lamp life at the end of the analysis period and consistent with the Federal Energy Management Program's Life-Cycle Costing Manualⁱ, DOE designates a discounted residual value for lamps or ballasts that have remaining value. For example, if a more efficacious lamp expires before the

end of the analysis period, DOE assumes that the lamp is replaced during the analysis period and credits the unused lamp life of this replacement lamp back as a residual value at the end of the analysis period.

DOE is conducting the LCC and PBP analyses on the baseline lamps from the representative product classes identified in Chapter 3. Table 8.1.1 shows the set of four representative product classes that DOE is evaluating in this analysis.

Table 8.1.1 Product Classes Analyzed in the LCC and PBP Analyses

General Service Fluorescent Lamps
4-Foot Medium Bipin, ≤4,500K
8-Foot Single Pin Slimline, ≤4,500K
8-Foot Recessed Double-Contact High-Output (HO), ≤4,500K
4-Foot T5 Miniature Bipin Standard Output (SO), ≤4,500K
4-Foot T5 Miniature Bipin High Output (HO), ≤4,500K
Incandescent Reflector Lamps
Standard-Spectrum, Voltage < 125V, Diameter > 2.5 Inches

8.1.2 Overview of LCC and PBP Inputs

As mentioned earlier, the LCC represents the total consumer expense over the analysis period, including purchase expenses, operating costs (including energy expenditures), and installation costs. DOE discounts future operating costs to the time of purchase and sums them over the analysis period. Due to the large variance of lamp lifetimes, for this rulemaking, DOE bases the analysis period on the longest life baseline lamp within a product class. The LCC calculation credits back the “residual value” of a lamp, or lamp and ballast, if it has any operating life remaining at the end of the analysis period. The residual value is the discounted total installed cost of a lamp, or lamp and ballast, multiplied by the percentage of the remaining life past the analysis period. The PBP represents the number of years it takes customers to recover the purchase price of more energy-efficient equipment through lower operating costs. The PBP is calculated as the change in first cost divided by the change in operating costs in the first year.

DOE categorizes inputs to the LCC and PBP analysis as follows: (1) inputs for establishing the purchase expense, otherwise known as the total installed cost; and (2) inputs for calculating the expenses incurred during the operation of the lamp, otherwise known as the operating cost. In addition, inputs to the LCC are used to calculate a residual value for any remaining product lifetime beyond the analysis period and replacement costs for those lamps whose service life is less than the analysis period.

The primary inputs for establishing the life-cycle cost and payback period are:

End-User Product Price: As discussed in Chapter 7, DOE starts with manufacturer catalog (“blue-book”) pricing, and applies discounts to develop low, medium, and high prices for all lamp types. The end-user product prices represent the consumer price before tax and installation.

Sales Tax: DOE then applies sales tax to convert the end-user product price to a final product price including sales tax. Chapter 7 describes the sales tax markup in detail.

Installation Cost: This input represents the cost to the commercial or industrial customers of installing the lamps or lamp systems. The installation cost represents all costs required to install the lamp or lamp system but does not include the end-user product price. The installation cost includes labor and overhead. Thus, the total installed cost equals the end-user product price including sales tax plus the installation cost.

Disposal Cost: After a GSFL reaches its end of life, some consumers pay to recycle those lamps. The disposal cost represents the cost of recycling a GSFL and is only applicable to those consumers in the commercial and industrial sectors.

The primary inputs for calculating the operating cost include the following:

Annual Operating Hours: The annual operating hours are the hours that a lamp is estimated to be in use during one year. The energy use characterization (Chapter 6) details how DOE determines the lamp operating hours as a function of end-user sector, geographic region, and building type.

Power Rating: The power consumption is the site-energy usage rate associated with operating the lamp system. The energy use characterization (Chapter 6) details how DOE determines the power ratings for the lamp and lamp-and-ballast systems considered in the analyses.

Electricity Prices: DOE uses the average price per kilowatt-hour (i.e., \$/kWh) paid by customers. DOE determines electricity prices using national average residential, commercial, and industrial electricity prices for the sample calculation. For the Monte Carlo distribution, DOE uses average residential, commercial, and industrial values for 13 regions and large States. DOE develops all electricity price inputs using 2006 EIA data.

Electricity Price Trends: DOE uses the EIA's *Annual Energy Outlook 2008 (AEO2008)*ⁱⁱ to forecast electricity prices. For the results presented in this chapter, DOE uses the *AEO2008* reference case to forecast future electricity prices.

Lifetime: Lifetime is the total hours in operation after which the consumer retires the lamp or components of a lamp system from service.

Discount Rate: The discount rate is the rate at which DOE discounts future expenditures to establish their present value.

Analysis Period: Analysis period is the time span over which DOE calculates the LCC.

The residual value calculation also uses all of the installed cost inputs as well as several operating cost inputs. Figure 8.1.1 depicts the relationships between the installed cost, operating cost, and residual value inputs for the calculation of the LCC and PBP. In this figure, the rectangular boxes indicate the inputs, the parallelograms indicate intermediate calculated values, and the diamond boxes indicate the analysis outputs (the LCC and PBP).

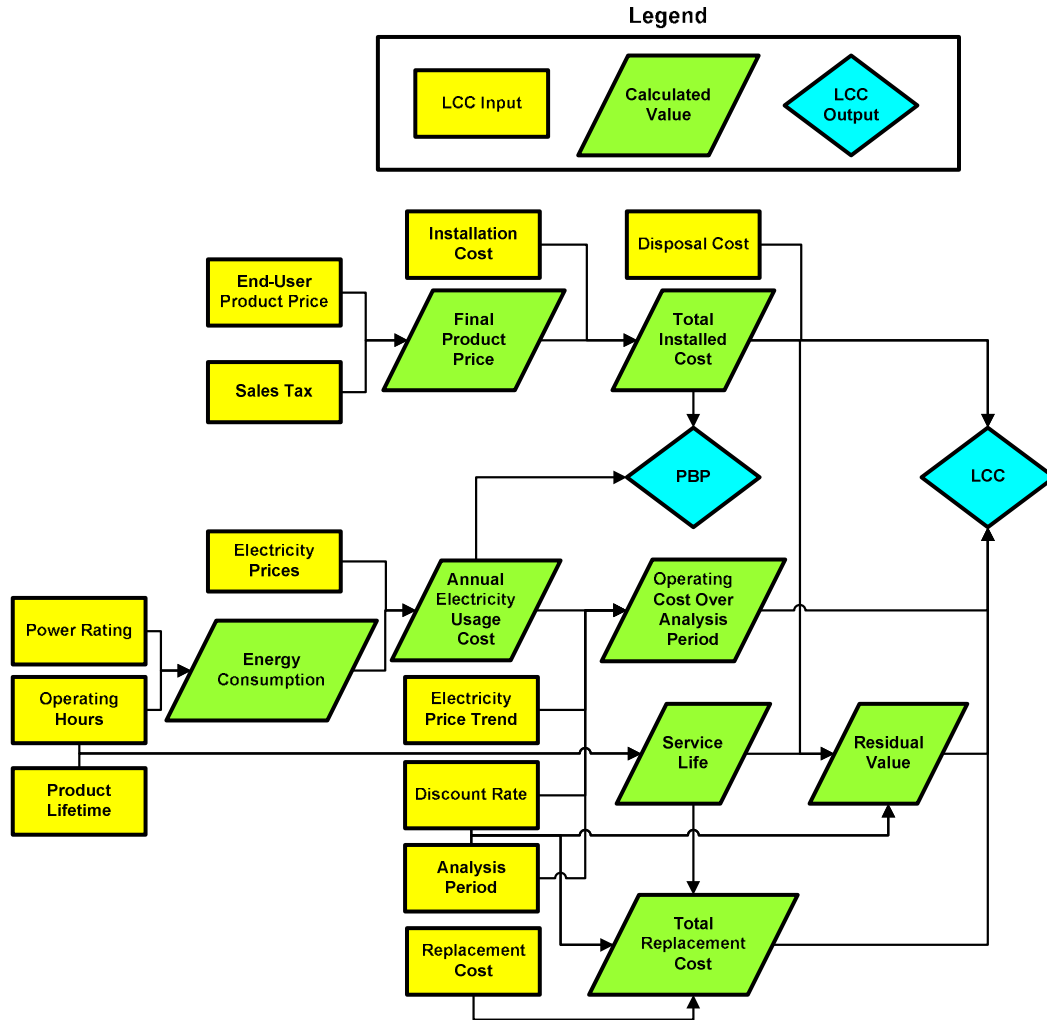


Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

Table 8.1.2 summarizes the input values that DOE uses to calculate the LCC and PBP for GSFL and IRL. Each row summarizes the total installed cost inputs, operating cost, replacement cost, and residual value inputs, including the lifetime, discount rate, and electricity price trend. DOE characterizes all of the total cost inputs with single-point values, but characterizes several of the operating cost inputs with probability distributions that capture the input's uncertainty and/or variability in the Monte Carlo analysis. Table 8.1.2 also lists the chapter of the Technical Support Document that details the inputs.

Table 8.1.2 Summary Information of Inputs for the Life-Cycle Cost and Payback Period Analyses

Factor	Weighted-Average Value	TSD Reference Section
Total Installed Cost Primary Inputs		
End-User Product Price	Varies with lamp and ballast	Chapter 7
Sales Tax	Varies by census region	Chapter 7
Installation Cost	Varies by equipment installed and sector	Chapter 8
Operating Cost Primary Inputs		
Annual Operating Hours	Vary by lamp type, sector, and building type.	Chapter 6
Power Rating	Varies with lamp type, and lamp or lamp-and-ballast system	Chapter 6
Electricity Prices	Vary by sector and census region	Chapter 8
Electricity Price Trends	Vary with price forecast scenario	Chapter 8
Discount Rate	Varies with sector	Chapter 8
Analysis Period	Varies with baseline lamp and annual operating hours.	Chapter 8
Replacement Cost and Residual Value Primary Inputs		
Total Installed Cost	Varies with lamp and ballast, census region, equipment installed and sector	Chapters 7, 8
Lifetime	Varies with lamp and system	Chapters 5, 8
Disposal Cost	Varies by lamp type and sector	Chapter 8
Discount Rate	Varies with sector	Chapter 8
Analysis Period	Varies with baseline lamp and annual operating hours.	Chapter 8

Sections 8.2 and 8.3 discuss the installed cost and operating cost inputs depicted in Table 8.1.2 .

8.2 LIFE-CYCLE COST INPUTS

8.2.1 Definition

LCC is the total customer cost over the life of a product, including total installed costs, operating costs, replacement costs, and residual value. Future operating costs and replacement costs are discounted to the analysis start year (2012) and summed over the analysis period. The residual value (if any) is credited back to the LCC, if the operating life of the standards case technology exceeds that of the analysis period. The LCC is defined by the following equation:

$$LCC = IC + \sum_{t=1}^N \left(\frac{OC_t + RC_t}{(1+r)^t} + \frac{DC}{(1+r)^t} \right) - \frac{RV}{(1+r)^N} \quad \text{Eq. 8.1}$$

where

$$\begin{aligned} LCC &= \text{life-cycle cost (\$),} \\ IC &= \text{total installed cost (\$),} \end{aligned}$$

- N = analysis period,
- \sum = sum over the analysis period, from year 1 to year N ,
- OC = operating cost (\$),
- RC = replacement cost (\$),
- r = discount rate,
- t = year for which operating cost, replacement cost, or disposal cost is determined,
- DC = disposal cost of the lamp, and
- RV = residual value for an analysis period, N .

DOE expresses all the costs in its LCC and PBP analyses in 2007 dollars.

8.2.2 Total Installed Cost Inputs

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

$$IC = FPP + INST$$

Eq. 8.2

where

- FPP = final product price (i.e., customer price for the product only, including sales tax), expressed in dollars, and
- $INST$ = installation cost or the customer price to install products (i.e., the cost for labor and materials), expressed in dollars.

In the product price determination (Chapter 7), DOE develops end-user product prices and sales taxes to derive final product prices. DOE then applies installation costs, where necessary, to derive the total installed costs for use in the LCC. The table below shows inputs to determine total installed costs.

Table 8.2.1 Inputs for Total Installed Costs

End-User Product Price (\$)
Sales Tax (\$)
Installation Cost (\$)

The end-user product price is the average purchase price a consumer pays before sales tax for lamp designs or lamp-and-ballast designs. The sales tax represents State and local sales taxes applied to the end-user product price. It is a multiplicative factor that increases the end-user product price. Installation cost is the cost to the customer of installing the lamps or lamp systems, and only applies in the commercial and industrial sectors. The installation cost represents all costs required to install the lamp or lamp-and-ballast system but does not include the final product price. The installation cost includes labor and overhead. Thus, the total installed cost equals the final product price plus the installation cost. DOE calculates the total installed cost for the lamps analyzed based on the following equation:

$$\begin{aligned}
 IC &= FPP + INST \\
 &= PRICE \times MU_{TAX} + INST
 \end{aligned}
 \tag{Eq. 8.3}$$

where

<i>IC</i>	=	total installed cost,
<i>FPP</i>	=	final product price,
<i>INST</i>	=	installation cost,
<i>PRICE</i>	=	end-user product price, and
<i>MU_{TAX}</i>	=	sales tax mark up

Chapter 7 provides detail on the end-user product price and sales tax. Discussion on the installation costs follows.

8.2.2.1 Installation Costs

DOE applies lamp and ballast installation costs only to lamps and lamp-and-ballast systems installed in the commercial and industrial sectors. DOE assumes that in the residential sector, the homeowner replaces the lamps and incurs no additional labor charge.

On September 19, 2000, DOE issued a final rule establishing energy conservation standards for ballasts (hereafter referred to as “the 2000 Ballast Rule”). 65 FR 56740 (Sept. 19, 2000); 10 CFR 430.23(m)(4). For GSFL, DOE obtains estimates of the prevalence of group versus spot relamping from the 2000 Ballast Rule. DOE then weighs the spot and group relamping times by the percent occurrence of spot versus group relamping to derive weighted averaged relamping times. According to the 2000 Ballast Rule, group relamping occurs, on average, 25 percent of the time for 4-foot medium bipin systems, 37 percent for 8-foot single pin slimline systems, and 31 percent for 8-foot recessed double contact high-output systems.ⁱⁱⁱ These percentages are used to calculate an average time to change GSFL lamp designs.

To account for installation costs for IRL, DOE uses relamping time estimates from the *RS Means Electrical Cost Data, 2007 (RS Means)*.^{iv} Table 8.2.2 lists average labor times to install a lamp (for IRL and GSFL) and a lamp and ballast (for GSFL only). For new construction, renovation, and major retrofit GSFL purchase events, DOE also adds 2.5 minutes to the labor times when installing lamps and ballasts to account for the installation of a luminaire disconnect. DOE adds this additional installation time because the 2005 National Electric Code requires a means for disconnecting luminaires before they are serviced for lamp or ballast replacements.^v

Table 8.2.2 Relamping Times for General Service Fluorescent Lamps and Incandescent Reflector Lamps*

Lamp Type	Spot Relamp Time <i>minutes</i>	Group Relamp Time <i>minutes</i>	Average Relamp Time <i>minutes</i>	Time to Install Lamps and Ballasts** <i>minutes</i>
General Service Fluorescent Lamps (Commercial and Industrial)				
2-Lamp Fixture - 4-Foot Medium Bipin, 4-Foot Miniature Bipin	27.0	14.0	23.8	30.0
3-Lamp Fixture - 4-Foot Medium Bipin	27.5	14.5	24.3	35.0
2-Lamp Fixture - 8-Foot Single Pin Slimline	20.5	10.5	16.8	55.0
2-Lamp Fixture - 8-Foot Recessed Double Contact High-Output	26.5	13.5	22.5	60.0
Incandescent Reflector Lamps (Commercial)				
All			4.0	N/A

*GSFL labor times are obtained from the 2000 Ballast Rule. IRL labor times are obtained from *RS Means*.

** For new construction, renovation, and major retrofit GSFL purchase events, labor times are increased by 2.5 minutes to allow for the installation of a luminaire disconnect.

For lamp-and-ballast installations, DOE derives labor rates for electricians and helpers from *RS Means*. Labor rates are the sum of the wage rate, employer-paid fringe benefits (i.e., vacation pay, employer-paid health, and welfare costs), and any appropriate training and industry advancement funds costs. An electrician's average hourly rate with overhead and profit is typically \$67.21 (in 2007\$), and a helper's average hourly rate is \$43.61 (in 2007\$). As in the 2000 Ballast Rule, DOE assumes that 50 percent of the electrician labor rate and 50 percent of the helper labor rate (for a total of \$55.41) comprise the lamp-and-ballast installation rate.

For lamp replacements in the commercial sector, DOE assumes that the task is performed by a general maintenance worker. The labor rate of \$15.94 (adjusted to 2007\$ from \$15.01 in 2005) was obtained from the U.S. Bureau of Labor Statistics for a General Maintenance Worker.^{vi} Using these labor rates and the labor times listed in Table 8.2.2, DOE derives the average cost to install a lamp and the average cost to install a lamp and ballast.

Table 8.2.3 Relamping and Lamp-and-Ballast Labor Cost for General Service Fluorescent Lamps and Incandescent Reflector Lamps

Lamp Type	Relamping Labor Cost	Labor Cost to Install Lamps and Ballast*
General Service Fluorescent Lamp (Commercial and Industrial)		
2-Lamp Fixture, 4-Foot Medium Bipin and 4-Foot Miniature Bipin	\$6.13	\$26.94
3-Lamp Fixture, 4-Foot Medium Bipin	\$6.26	\$31.43
2-Lamp Fixture, 8-Foot Single Pin Slimline	\$4.34	\$49.39
2-Lamp Fixture, 8-Foot Recessed Double Contact High Output	\$5.80	\$53.88
Incandescent Reflector Lamps (Commercial)		
All	\$1.03	N/A

*For new construction, renovation, and major retrofit GSFL purchase events, DOE increases the labor cost to install lamps and ballast by \$2.31 to allow for the installation of a luminaire disconnect.

8.2.3 Operating Cost Inputs

The operating cost represents the costs incurred in the operation of the lamp or lamp-and-ballast system. Table 8.2.4 lists the inputs for operating costs. The analysis period, discount rate, and effective date of the standard are required to determine the operating cost and for establishing the operating cost present value. The electricity consumption for the baseline and other ELs examined enable comparison of standards' operating costs.

Table 8.2.4 Inputs for Operating Costs

Annual Operating Hours
Power Rating
Electricity Prices
Electricity Price Trends
Discount Rate
Analysis Period

The annual operating hours are the estimated hours that a lamp is in use during one year. Power rating refers to the rate of site energy usage associated with operating the lamp or lamp-and-ballast system. Both the annual operating hours and power rating are used to calculate the total annual energy consumption. Electricity prices used in the analysis are the price per kilowatt-hour in cents or dollars (e.g., \$/kWh) paid by each customer for electricity. DOE uses electricity price trends to forecast electricity prices for future year analysis. These trends with the electricity price and annual energy consumption are used to calculate the energy cost in each year. DOE defines energy cost by the following equation:

$$\begin{aligned}
 OC &= E_{cons} \times EP \times EPT \\
 &= (PWR \times OH) \times EP \times EPT
 \end{aligned}
 \tag{Eq. 8.4}$$

where

- OC = operating costs,
- E_{cons} = annual energy consumed,
- EP = electricity price,
- EPT = electricity price trend factor relative to 2007,
- PWR = power rating (rate of energy use, measured in watts), and
- OH = annual operating hours.

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

8.2.3.1 Operating Hours

The energy use characterization (Chapter 6) details how DOE determines the annual energy consumption for baseline and standard-compliant products. An important input to determining the energy consumption is the total hours per year that the product is in operation.

The operating hours are also used to calculate the lamp service life, which is ultimately used in calculating the total replacement cost and residual value.

As described in Chapter 6, DOE establishes operating hour distributions for GSFL and IRL. In conjunction with data from LMC, DOE uses data from EIA’s CBECS 2003, RECS 2001, and the MECS 2002. These EIA studies provide information on the distribution of buildings within the United States by building type and census division. DOE associates the LMC’s operating hour data by building type with the EIA’s data by building type and census division to derive operating hours by census division and large States. This allowed DOE to correlate its electricity price distribution and sales tax distribution (see Chapter 7) with its operating hour distribution by census division and large State in the LCC spreadsheet. Table 8.2.5 presents the mean operating hours for GSFL and IRL for each sector.

As described in section 8.2.4, the average useful lifetime of ballasts in the residential sector is approximately 15 years.^{vii} Because using average operating hours would cause ballasts to reach the end of their lives before the baseline lamps failed in the residential sector, DOE has chosen to use higher operating hours for the lamp failure event. In order to represent the best possible LCC savings of a consumer replacing a failed lamp, DOE has chosen to use the highest possible LCC savings of a consumer replacing a failed lamp, DOE has chosen to use the highest operating hours in the LMC for GSFL. These operating hours result in a lamp failure of the baseline lamp whose lifetime is 15,000 hrs after 12.5 years of operation. The highest number of operating hours of GSFL in the residential sector is shown in Table 8.2.6..

Table 8.2.5 Average Operating Hours by Sector and Lamp Type

Sector	Lamp Category	Average Annual Operating Hours <i>hours/year</i>
Residential	GSFL	789
	IRL	884
Commercial	GSFL	3,435
	IRL	3,450
Industrial	GSFL	4,795

Table 8.2.6 High Operating Hours for GSFL in the Residential Sector

Sector	Lamp Category	High Annual Operating Hours <i>hours/year</i>
Residential	GSFL	1,210

8.2.3.2 Power Rating

As described in the energy use and end load characterization (Chapter 6), DOE uses the power rating (in watts) and the annual operating hours (in hours) to calculate the annual energy usage (in kilowatt hours) of the lamp and lamp-and-ballast designs DOE considers.

General Service Fluorescent Lamps

Because a fluorescent lamp requires a ballast to operate, DOE analyzes these lamps as systems consisting of both lamps and ballasts. Therefore, in the “lamp only replacement” and “lamp-and-ballast replacement” scenarios, the system input power represents the energy consumption rate of both the lamps and ballast, and therefore is different than simply the rated lamp power. When each lamp is paired with ballasts with differing ballast factors (BFs), the lamp systems have different power ratings. See Chapter 6 for detailed results showing power ratings and annual energy consumption estimates given a BF and lamp power and operating hours.

Incandescent Reflector Lamps

Because an IRL lamp system consists of only the lamp, the system’s annual energy use is simply the product of the rated power and operating hours of the lamp. Detailed tables depicting the power rating and annual energy consumption for all of the IRL lamp designs are available in Chapter 6.

8.2.3.3 Electricity Prices

DOE estimates electricity prices for residential, commercial, and industrial consumers in each of the 13 regions and large States by using EIA Form 861 data.^{viii} Table 8.2.7 lists the 13 geographic regions. The EIA Form 861 data are published annually and include annual electricity sales in kilowatt hours; revenues from electricity sales; and number of consumers for the residential, commercial, and industrial sectors for every utility serving final consumers. The calculation of an average electricity prices proceeds in two steps:

- 1) For each utility, estimate an average residential, commercial, or industrial price by dividing the residential, commercial, or industrial revenues by residential, commercial, or industrial sales.
- 2) Calculate a regional average price, weighting each utility with customers in a region by the number of residential, commercial, or industrial consumers served in that region.

The calculation uses the most recent available EIA data at the time the analysis was conducted, from 2006. Table 8.2.7 shows the results for each geographic region. Because DOE conducted the LCC and PBP analyses in 2007\$, it needed to convert all electricity prices into 2007\$. To perform the necessary monetary conversion, DOE uses the consumer price index (CPI) to convert the electricity prices from 2006\$ to 2007\$. As described in the following section on electricity price trends, DOE normalizes energy prices to 2007. Therefore, to forecast energy prices for any given future year, DOE establishes energy prices for 2007. In Table 8.2.7, DOE uses data from the *AEO2008* to estimate the electricity prices for 2007.^{ix} DOE multiplies the electricity price in 2006 by the ratio of the *AEO2008*-estimated residential, commercial, or industrial prices for 2007 and 2006.

Table 8.2.7 Electricity Prices by Census Division, 2007

Census Division	Electricity Prices,* 2007		
	Residential	Commercial	Industrial
	2007\$/kWh	2007\$/kWh	2007\$/kWh
New England	\$0.164	\$0.151	\$0.085
Middle Atlantic	\$0.117	\$0.103	\$0.053
East North Central	\$0.095	\$0.082	\$0.049
West North Central	\$0.085	\$0.072	\$0.068
South Atlantic	\$0.092	\$0.080	\$0.049
East South Central	\$0.083	\$0.083	\$0.059
West South Central	\$0.091	\$0.083	\$0.059
Mountain	\$0.092	\$0.081	\$0.052
Pacific	\$0.092	\$0.091	\$0.045
New York State	\$0.179	\$0.161	\$0.051
California	\$0.147	\$0.136	\$0.071
Texas	\$0.131	\$0.121	\$0.086
Florida	\$0.116	\$0.102	\$0.082
U.S. Weighted Average	\$0.112	\$0.101	\$0.063

* DOE converts dollars to 2007\$ by multiplying costs in 2006\$ by the ratio of 2007 CPI (207.34) to 2006 CPI (201.6). DOE converts the price for 2006 to the price in 2007 by multiplying the 2006 price by the ratio of the average *AEO* electricity price in 2007 to the average *AEO* electricity price in 2006.

8.2.3.4 Electricity Price Trend

The electricity price trend projects the future cost of electricity to 2030. DOE calculates the LCC and PBP using three separate projections from *AEO2008*: reference, low economic growth, and high economic growth.^x These three cases reflect the uncertainty of economic growth in the forecast period. The high and low growth cases show the projected effects of alternative growth assumptions on energy markets. DOE normalizes these three *AEO2008* scenarios to the 2007 electricity price, and then uses that electricity price factor to scale the 2007 electricity prices. Figure 8.2.1 through Figure 8.2.3 show the residential, commercial, and industrial electricity price trends, respectively, based on the three *AEO2008* projections. The LCC results presented in this chapter are based on the *AEO2008* reference case.

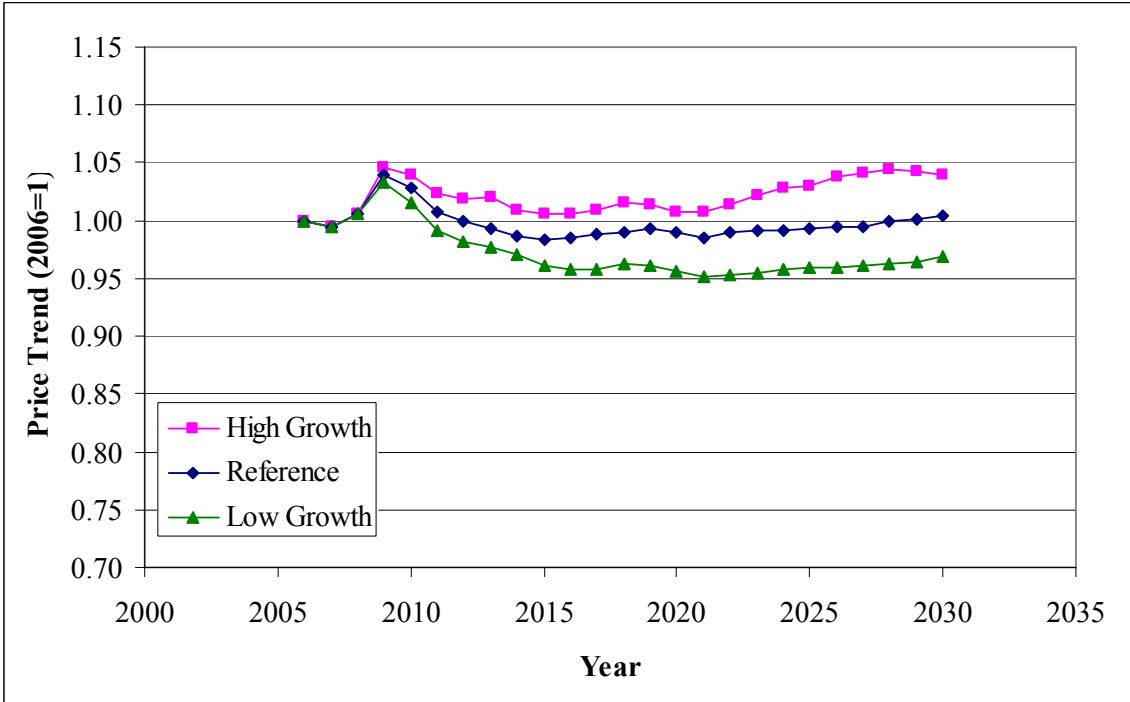


Figure 8.2.1 Residential Sector Electricity Price Trend

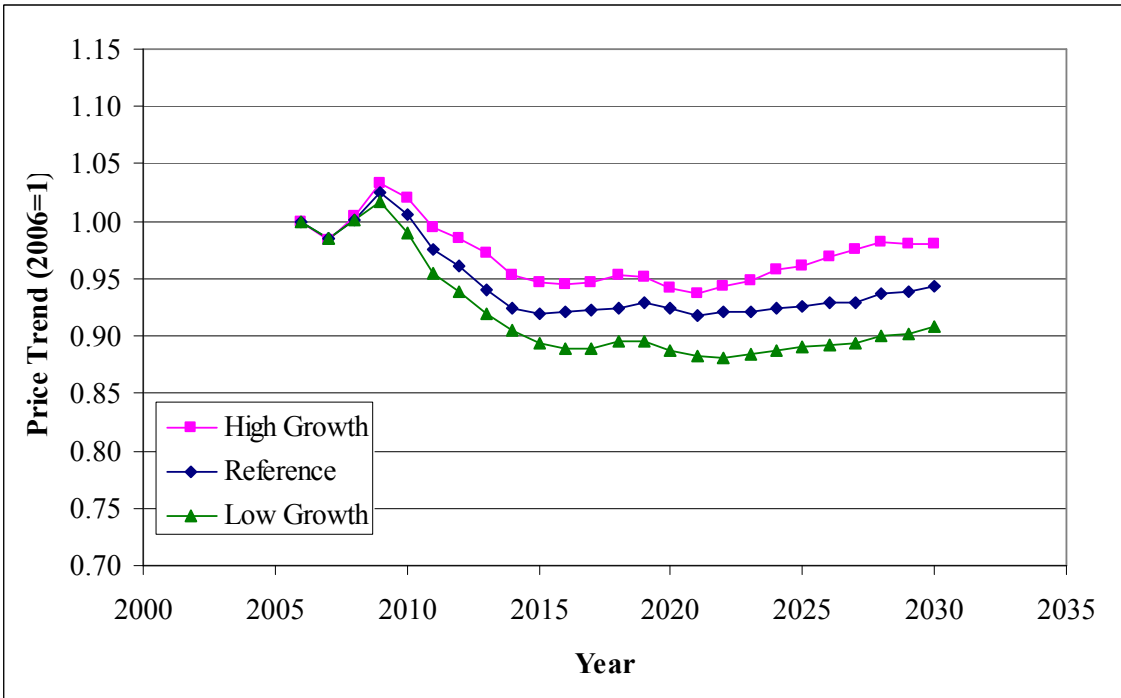


Figure 8.2.2 Commercial Sector Electricity Price Trend

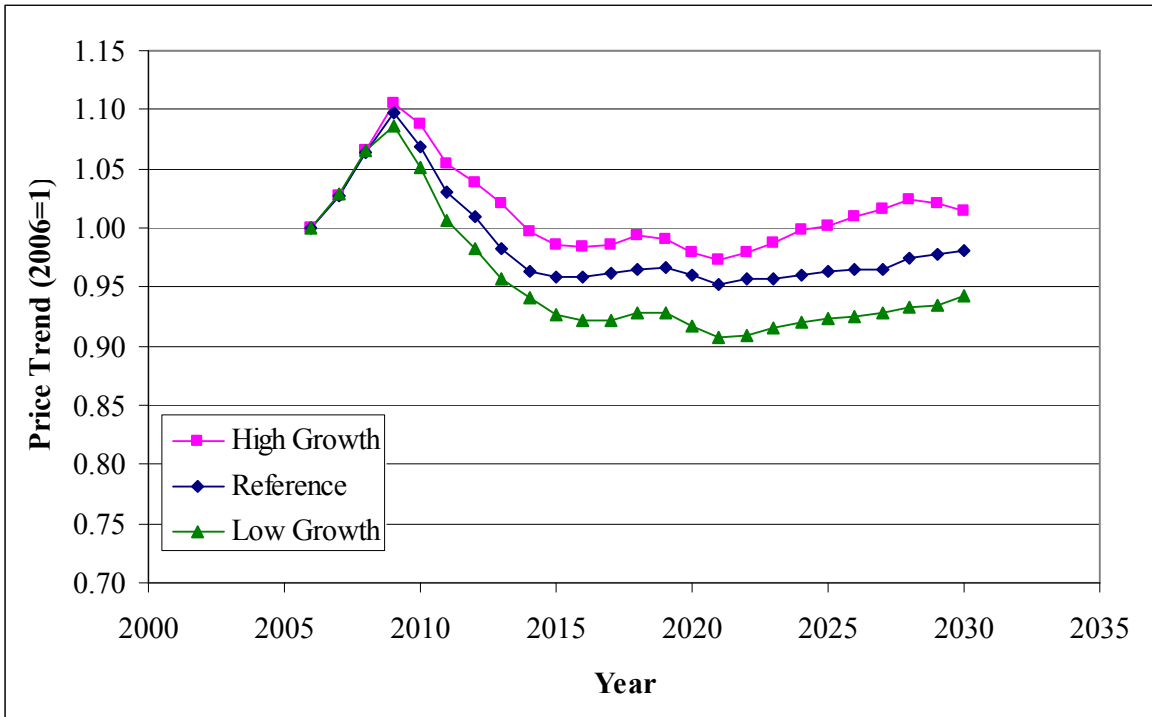


Figure 8.2.3 Industrial Sector Electricity Price Trend

In the LCC spreadsheet, these electricity price trends are used to project electricity prices into the future, which are then multiplied by the annual energy usage. The resulting operating costs are presented in both the LCC spreadsheets and the LCC results tables in this chapter.

8.2.4 Lifetime

DOE defines lifetime as the age in hours in operation when a lamp or ballast is retired from service. DOE uses published manufacturing literature when available to derive lamp lifetimes. When published manufacturing literature on lamp lifetime is not available, DOE derives lamp lifetimes in the engineering analysis (Chapter 5). For GSFL, DOE bases its calculation of lamp lifetimes for both base and standards case lamps on 3-hour start data.

Like the calculation of relamping costs, DOE averages the group versus spot relamping impact on lifetime by their percent occurrence for GSFL. DOE assumes a lamp subject to group re-lamping practices operates for 75 percent of its rated life. DOE obtained this estimate from the 2000 Ballast Rule. DOE then applies this life impact factor to the rated lifetimes from the manufacturing literature for the GSFL it is analyzing. For 4-foot medium bipin lamps and 4-foot miniature bipin lamps, the average lifetime DOE uses in the analysis is 94 percent of the rated lifetime. For 8-foot single pin slimline lamps, the average lifetime is 91 percent of the rated lifetime. For 8-foot recessed double contact HO lamps, the average lifetime is 92 percent of the rated lifetime. DOE does not assume an impact on lifetime due to group re-lamping for IRL.

As discussed in the technology assessment (Chapter 3), many technology options to improve GSFL and IRL efficiencies affect the lifetime of the lamp. For this reason, the baseline and standard level designs for the LCC and PBP analyses have a wide range of lifetimes.

For ballasts in the commercial and industrial sectors, DOE uses the average ballast lifetime used in the 2000 Ballast Rule (49,054 hrs). Using DOE’s estimate of 49,054 hours and average operating hours for GSFL in the commercial sector, the lifetime of an average ballast is approximately 14.2 years. This lifetime is consistent with a study on the “measure life” of ballasts (i.e., the true service life of a ballast in the field), which found that the average ballast lifetime after a retrofit in the commercial sector is 13 years, and the average ballast lifetime after new construction is 15 years.^{xi} DOE found in a separate measure life report that the average fixture and ballast in the residential sector lasts for 15 years. Therefore, in its residential sector analysis for GSFL, DOE established 15 years as the average ballast lifetime in the residential sector.^{xiii} Assuming the average annual operating lifetime of a GSFL in the residential sector of 789 hours as discussed in section 8.2.3.1, the ballast lifetime is therefore 11,835 hours in the residential sector.

8.2.5 Replacement Cost

As stated earlier, the lifetime is the age (total hours in operation) at which the lamp or components of a lamp system are retired from service. The lifetime paired with the operating hours yields the service life of the lamp in years. Replacement costs include the labor and materials costs associated with replacing a lamp at the end of its lifetime. By using the service life and replacement cost, DOE calculates the total replacement cost each year.

Replacement costs are the labor and materials costs associated with replacing a lamp at the end of its lifetime. Because the lifetimes of GSFL and IRL lamp designs vary within each of their respective product classes, it is at times necessary to replace a lamp within the analysis period. Generally, if the analysis period is greater than the lamp service lifetime for a particular baseline or standard level design, those lamps will require replacement to reach the end of the analytical period. Each year in which a lamp reaches the end of its life, a new lamp is purchased and installed at the beginning of that year, and the first cost and installation cost are discounted back to the base year of the analysis period. During years in which replacement is necessary, DOE based the replacement costs on the total installed cost inputs, as seen in the following equation:

$$\begin{aligned}
 RC &= FPP_L + INST_L \\
 &= PRICE_L \times MU_{TAX} + INST_L
 \end{aligned}
 \tag{Eq. 8.5}$$

where

RC	=	replacement cost, expressed in dollars,
FPP_L	=	final product price (price for the product only) expressed in dollars,
$INST_L$	=	installation cost,
$PRICE_L$	=	end-user product price expressed in dollars, and
MU_{TAX}	=	sales tax.

For the years when no replacement is necessary, the replacement costs are set to zero. For GSFL, the replacement costs only include the end-user product price of the lamp and the installation cost of the lamp, rather than prices or costs associated with the entire lamp-and-ballast system. For the LCC and PBP analyses, DOE selects time periods of analysis that do not

require replacement of the ballast. For this reason, only lamp price and labor costs are included in the calculation of total installed costs. For IRL, because there is no ballast in the analysis, the replacement cost is simply the total installed cost of the lamp itself.

8.2.6 Disposal Cost

When a GSFL fails, some consumers choose to recycle the lamp. The cost of recycling the GSFL is its disposal cost. DOE performed research on recycling costs for GSFL and found that, on average, disposing of a GSFL costs about 10 cents per linear foot.^{xiii} A report released by the Association of Lighting and Mercury Recyclers in 2004 noted that approximately 30% of lamps used by businesses and 2 percent of lamps in the residential sector are recycled.^{xiv} Because a relatively large percentage of consumers recycle lamps in the commercial and industrial sectors, DOE applies a cost of 10 cents per linear foot every time a lamp is replaced during the LCC analysis period. For 4-foot lamps, the disposal cost is \$0.40 per lamp while for 8-foot lamps, the disposal cost is \$0.80 per lamp. The disposal cost also impacts the residual value of lamps that operate beyond the end of the analysis period (described in 8.2.10). In the Monte Carlo analysis, DOE assumes that commercial and industrial consumers pay recycling costs for approximately 30% of lamp failures. Because few residential sector consumers recycle lamps, DOE does not apply the disposal costs to this sector. Disposal costs are also not applied to the LCC analysis for IRL in any sector because consumers do not pay for their disposal.

8.2.7 Analysis Period

The analysis period is the time span over which the LCC is calculated. To account for variability in lifetime of lamp designs, DOE develops a consistent analytical time period—comparing more efficacious lamps against a baseline lamp over the lifetime of the longest-lived baseline lamp in a particular product class. When this analysis period is shorter than the lifetime of the replacement lamp, DOE accounts for the remaining life of the replacement lamp as a residual value. When the analysis period is longer than the lifetime of the replacement lamp, a second replacement lamp is installed, and if any operating life of that second replacement lamp remains at the end of the analysis period, then its residual value is added back into the LCC. By using the average annual operating hours paired with published lamp lifetimes, DOE calculates the lamp service lifetime in years.

For the IRL and the commercial and industrial sector GSFL LCC analyses, DOE bases the analysis period on the longest baseline lamp life in a certain product class divided by the annual operating hours of that lamp. If the user chooses to run the LCC using weighted average values (i.e., in “sample calculation” mode), then the analysis period is based on the longest baseline lamp life divided by the average annual operating hours for that lamp in a chosen sector, or a multiple thereof. For example, the longest lived baseline IRL is 3,000 hours. If the user chooses to analyze this lamp in the commercial sector, then the analysis period is the lamp lifetime of 3,000 hours divided by the average annual operating hours of IRL in the commercial sector, 3,450 hours per year, or 0.9 years. To allow users to compare the cost of IRL over multiple lamp lifetimes, one can select a multiple of this analysis period (i.e., 1.8, 2.7, or 3.6 years). If the user chooses to run the LCC using the Monte Carlo simulation (i.e., in “Crystal Ball” mode), the analysis period is based on the longest baseline lamp life divided by the annual operating hours chosen by Crystal Ball[®]. For example, the user may choose to run IRL in the

commercial sector using Crystal Ball[®]. If Crystal Ball[®] selects a building that is used for religious worship, the analysis period for IRL for that selection will be based on a lamp lifetime of 3,000 hours divided by the annual operating hours of IRL in a building used for religious worship 1,609 hours per year, or 1.9 years. Users cannot select a multiple of this analysis period when using the Monte Carlo simulation.

For the residential sector GSFL LCC analysis, DOE uses the useful life of a baseline lamp for a specific event. Because this lifetime varies by event, DOE uses a different analysis period for the lamp replacement event than that used for the ballast failure and new construction and renovation events. Although lamp replacements do not occur for all lamps in the residential sector, replacements do occur for lamps with operating hours that yield a lamp lifetime that is shorter than the fixture or ballast. When using the highest GSFL operating hours in the residential sector, as discussed in section 8.2.3.1, the shortest lifetime of the baseline lamp is approximately 12.5 years. When this lamp is replaced at 12.5 years, the fixture and ballast, whose lifetime is 15 years, have another 2.5 years of life remaining. Therefore, for GSFL in the residential sector, the longest useful life of the baseline replacement lamp is 2.5 years or 1,972 hrs. At the end of this lifetime, the ballast and fixture are replaced. For the lamp replacement event in the residential sector, the analysis period is therefore 2.5 years.

For the ballast failure and new construction and renovation events, DOE uses average operating hours in the residential sector and assumes that a consumer will purchase a new lamp after the ballast fails. Because the ballast lifetime exceeds that of the lamp lifetime when under average operating hours conditions, DOE assumes that the ballast lifetime of 15 years limits the lamp lifetime. Therefore for GSFL in the residential sector, the useful life of the baseline lamp and therefore the analysis period is 15 years for the ballast failure and new construction and renovation events.

8.2.8 Discount Rate

The discount rate is the rate at which DOE discounts future expenditures to establish their present values. DOE derives the discount rates for the lamps rulemaking separately for residential and commercial/industrial consumers. For residential consumers, DOE estimates the discount rate by looking across all possible debt or asset classes that might be used to purchase lamps. For the commercial and industrial consumers, DOE estimates the cost of capital for commercial and industrial companies by examining both debt and equity capital, and develops an appropriately weighted average of the cost to the company of equity and debt financing.

8.2.8.1 Residential Discount Rate

GSFL and IRL are comparatively low-cost products for households to replace. With retail prices under one dollar for certain lamp types, households typically purchase lamps as needed. DOE's approach involves identifying all possible debt or asset classes that might be used to purchase replacement equipment, including household assets that might be affected

indirectly.¹ DOE does not include debt from primary mortgages and equity of assets considered non-liquid (such as retirement accounts), since these would likely not be used to finance replacement lamp purchases. DOE estimates the average shares of the various debt and equity classes in the average U.S. household equity and debt portfolios using the Federal Reserve's *Survey of Consumer Finances (SCF)* data for 1989, 1992, 1995, 1998, 2001, and 2004.^{xv} Table 8.2.8 shows the average shares of each considered class. DOE uses the mean share of each class across the six survey years (15 years) as the basis for estimating household financing of lamps and lighting equipment.

Table 8.2.8 Average Percentage Shares of Household Debt and Equity Types

Type	1989 SCF	1992 SCF	1995 SCF	1998 SCF	2001 SCF	2004 SCF	Mean %
Home Equity Loans	4.3	4.5	2.7	2.8	2.8	4.4	3.6
Credit Cards	1.6	2.1	2.6	2.2	1.7	2.0	2.0
Other Installment Loans	2.8	1.7	1.4	1.7	1.1	1.3	1.7
Other Residential Loans	4.4	6.9	5.2	4.3	3.1	5.8	4.9
Other Line of Credit	1.1	0.6	0.4	0.2	0.3	0.5	0.5
Checking Accounts	5.8	4.7	4.9	3.9	3.6	4.2	4.5
Savings and Money Market	19.2	18.8	14.0	12.8	14.2	15.1	15.7
Certificate of Deposit (CD)	14.5	11.7	9.4	7.0	5.4	5.9	9.0
Savings Bond	2.2	1.7	2.2	1.1	1.2	0.9	1.5
Bonds	13.8	12.3	10.5	7.0	7.9	8.4	10.0
Stocks	22.4	24.0	25.9	36.9	37.5	28.0	29.1
Mutual Funds	8.0	11.1	20.9	20.1	21.3	23.4	17.5
Total	100	100	100	100	100	100	100

DOE estimates interest or return rates associated with each type of equity and debt. The data source for the interest rates for loans, credit cards, and lines of credit is the Federal Reserve Board's *SCF* in 1989, 1992, 1995, 1998, 2001, and 2004. The top half of Table 8.2.9 shows the average nominal interest rates in each year and the inflation rates used to calculate real rates. For home equity loans, DOE calculates effective interest rates in a similar manner as for mortgage rates, since interest on such loans is tax deductible. The bottom half of the table shows the average effective real interest rates in each year and the mean rate across all the years. Since the interest rates for each debt carried by households in these years were established over 15 years, DOE believes they are representative of rates that may be in effect in 2012.

¹ An indirect effect would arise if a household sold assets to pay off a loan or credit card debt that might have been used to finance the actual lamp purchase.

Table 8.2.9 Average Nominal and Real Interest Rates for Household Debt Classes

Type	1989 SCF	1992 SCF	1995 SCF	1998 SCF	2001 SCF	2004 SCF	Mean %
Nominal Interest Rates %							
Home Equity Loans	11.5	9.6	9.6	9.8	8.7	5.7	9.2
Credit Cards*	-	-	14.2	14.5	14.2	11.7	13.6
Other Installment Loans	9.0	7.8	9.3	7.8	8.7	7.4	8.3
Other Residential Loans	8.8	7.6	7.7	7.7	7.5	6.0	7.5
Other Line of Credit	14.8	12.7	12.4	11.9	14.7	8.8	12.5
Inflation rate	4.82	3.01	2.83	1.56	2.85	2.66	
Real Interest Rates %							
Home Equity Loans	3.8	4.3	4.4	5.8	3.8	1.9	4.0
Credit Cards*	-	-	11.0	12.7	11.1	9.1	11.0
Other Installment Loans	4.9	5.8	7.0	6.6	6.1	5.4	6.0
Other Residential Loans	4.0	4.7	4.8	6.0	4.6	3.3	4.6
Other Line of Credit	9.6	9.4	9.3	10.2	7.3	6.0	8.7

* No interest rate data available for credit cards in 1989 or 1992.

To account for variation among new households, DOE samples a rate for each household from a distribution of rates for each of the above debt classes. DOE develops a probability distribution of interest rates for each debt class based on the *SCF* data. Appendix 8C presents the probability distribution of interest rates for each debt class that DOE used in the LCC and PBP analyses.

Similar rate data are not available from the *SCF* for the asset classes, so DOE derives data for these classes from national historical data. The interest rates associated with certificates of deposit (CDs),^{xvi} savings bonds,^{xvii} and bonds (AAA corporate bonds)^{xviii} are from Federal Reserve Board time-series data 1977-2005. DOE assumes rates on checking accounts to be zero. Rates on savings and money market accounts are from Cost of Savings Index data covering 1984-2005.^{xix} The rates for stocks are the annual returns on the Standard and Poor's (S&P) 500 1977-2005.^{xx} The mutual fund rates are a weighted average of the stock rates (two-thirds weight) and the bond rates (one-third weight) in each year from 1977 to 2005. DOE adjusts the nominal rates to real rates using the annual inflation rate in each year. Average nominal and real interest rates for the classes of assets are shown in Table 8.2.10. Since the interest and return rates for each asset type cover a range of time, DOE believes they are representative of rates that may be in effect in 2012.

Table 8.2.10 Average Nominal and Real Interest Rates for Household Equity Types

Type	Average Nominal Rate %	Average Real Rate %
Checking Accounts	--	0.0
Savings and Money Market	5.5	2.3
CDs	6.9	2.4
Savings Bonds	8.0	3.5
Bonds	8.8	4.2
Stocks	13.3	8.8
Mutual Funds	11.6	7.0

To account for variation among new households, DOE samples a rate for each household from a distribution of rates for each of the above asset types. DOE develops a normal probability distribution of interest rates for each asset type by using the mean value and standard deviation from the distribution. Appendix 8C presents the probability distribution of interest rates for each asset type that DOE used in the LCC and PBP analysis.

Table 8.2.11 summarizes the mean real effective rates of each type of equity or debt. DOE determines the average share of each debt and asset using *SCF* data for 1989, 1992, 1995, 1998, 2001, and 2004. Each year of *SCF* data provides the debt and asset shares for U.S. households. DOE averages the debt and asset shares over the six years of survey data to arrive at the shares shown below. The average rate across all types of household debt and equity, weighted by the shares of each class, is 5.6 percent.

Table 8.2.11 Shares and Interest or Return Rates Used for Household Debt and Equity Types

Type	Average Share of Household Debt Plus Equity %*	Mean Effective Real Rate %**
Home Equity Loans	3.6	4.0
Credit Cards	2.0	11.0
Other Installment Loans	1.7	6.0
Other Residential Loans	4.9	4.6
Other Line of Credit	0.5	8.7
Checking Accounts	4.5	0.0
Savings and Money Market Accounts	15.7	2.3
CDs	9.0	2.4
Savings Bonds	1.5	3.5
Bonds	10.0	4.2
Stocks	29.1	8.8
Mutual Funds	17.5	7.0
Total/Weighted-Average Discount Rate	100	5.6

* Not including primary mortgage or retirement accounts.

** Adjusted for inflation and, for home equity loans, loan interest tax deduction.

8.2.8.2 Commercial Discount Rate

Most companies use both debt and equity capital to fund investments; for most companies, therefore, the cost of capital is the weighted average of the cost to the firm of equity and debt financing.^{xxi}

DOE estimates the cost of equity financing using the Capital Asset Pricing Model (CAPM). The CAPM, among the most widely used models to estimate the cost of equity financing, assumes that the cost of equity is proportional to the amount of systematic risk associated with a firm. For example, the cost of equity financing tends to be high when a firm faces a large degree of systematic risk, and the cost tends to be low when the firm faces a small degree of systematic risk.

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

Following this approach, the cost of equity financing for a particular company is by the equation:

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

where

k_e	=	the cost of equity for a company, expressed in dollars,
R_f	=	the expected return of the risk free asset, expressed in dollars,
β	=	the risk coefficient, and
ERP	=	the expected equity risk premium, expressed in dollars.

The cost of debt financing (k_d) is the yield or interest rate paid on money borrowed by a company (raised, for example, by selling bonds). As defined here, the cost of debt includes compensation for default risk and excludes deductions for taxes.

DOE estimates the cost of debt for companies by adding a risk adjustment factor to the current yield on long-term corporate bonds (the risk-free rate). This procedure is used to estimate current and future company costs to obtain debt financing. The adjustment factor is based on indicators of company risk, such as credit rating or variability of stock returns.

The discount rate of companies is the weighted average cost of debt and equity financing, less expected inflation. DOE estimates the discount rate using the equation:

$$k = k_e \times w_e + k_d \times w_d \quad \text{Eq. 8.7}$$

where

- k = the (nominal) cost of capital,
- k_e and k_d = the expected rates of return on equity and debt, respectively, and
- w_e and w_d = the proportion of equity and debt financing, respectively.

The real discount rate deducts expected inflation from the nominal rate.

The expected return on risk-free assets, or the risk-free rate, is defined by the current yield on long-term (20-year) Government bonds, as suggested by Ibbotson’s Associates^{xxii} and Damodaran.^{xxiii} The ERP represents the difference between the expected (average) stock market return and the risk-free rate. As Table 8.2.12 shows, DOE uses an ERP estimate of 5.1 percent, which it took from the Damodaran Online site (a private website associated with New York University’s Stern School of Business, which aggregates information on corporate finance, investment, and valuation).^{xxiv}

DOE calculates an expected inflation of 3.1 percent from the average of five quarters’ change in GDP prices.^{xxv} DOE obtained the cost of debt, percent debt financing, and systematic firm risk from the Damodaran Online website. Table 8.2.12 shows average values across all private companies. However, the cost of debt, percent debt financing, and systematic firm risk vary by sector.

Table 8.2.12 Variables Used to Estimate Company Discount Rates

Variable	Symbol	Average Value %	Source
Risk-Free Asset Return	R_f	7.3	Damodaran Online
Equity Risk Premium	ERP	5.6	Damodaran Online
Expected Inflation	R	3.1	U.S. Bureau of Economic Analysis
Cost of Debt (After Tax)	k_d	6.9	Damodaran Online
Percent Debt Financing	w_d	25.6	Damodaran Online
Systematic Firm Risk	B	1.02	Damodaran Online

In the commercial building sector, lamps are purchased and owned by commercial building property owners, commercial companies, industrial companies and the Government. DOE uses a sample of 4,207 companies drawn from these owner categories to represent lamp purchasers. It took the sample from the list of companies included in the Value Line investment survey^{xxvi} and listed on the Damodaran Online website. DOE obtained the cost of debt, the firm beta, the percent of debt and equity financing, the risk-free return, and the equity risk premium from Damodaran Online.

DOE estimates the cost of debt financing for these companies from the long-term Government bond rate and the standard deviation of the stock price. For Government-office-type owners, the discount rate represents an average of the Federal rate and the State and local bond rate. DOE drew the Federal rate directly from the U.S. Office of Management and Budget

discount rate for investments in Government building energy efficiency.^{xxvii} DOE estimates the State and local discount rate from the interest rate on State and local bonds between 1977 and 2001.^{xxviii} DOE uses this information to estimate the weighted-average cost of capital for the sample of companies included in the commercial property owner, commercial, and industrial company database.

The cost of capital may be viewed as the discount rate that should be used to reduce the future value of typical company project cash flows. It is a nominal discount rate, since anticipated future inflation is included in both stock and bond expected returns. Deducting expected inflation from the cost of capital provides estimates of the real discount rate by ownership category (see Table 8.2.13). The mean real discount rate for these companies varies between 2.3 percent (Government offices) and 8.3 percent (industrial companies).

Table 8.2.13 Real Discount Rates by Lamp Ownership Category

Ownership Category	SIC Codes*	Mean Real Discount Rate %	Standard Deviation %	Number of Observations
Industrial Companies	1 - 4	7.6	2.3	1942
Commercial Companies	5 - 8	8.3	2.4	2339
Commercial Property Owners	6720	6.3	2.0	7
Government Offices	N/A	2.3	1.1	N/A

* SIC Codes refer to the U.S. Standard Industrial Classification system.

Source: Lawrence Berkeley National Laboratory (LBNL) calculations based on firms sampled from the Damodaran Online website as performed for the distribution transformers rulemaking.

DOE's approach for estimating the cost of capital provides a measure of the discount rate spread as well as the average discount rate. DOE infers the discount rate spread by ownership category from the standard deviation, which ranges between 1.1 percent and 2.4 percent (Table 8.2.13).

Different combinations of commercial property owners and commercial, industrial, and Government buyers purchase the lamp types considered in the LCC analysis. Accordingly, DOE constructs the discount rates associated with each building sector from different combinations of commercial property owner, commercial, industrial, and Government rates.

To estimate the share of each ownership category in total commercial sector purchases of lamps, DOE uses the share of each category in total commercial building square footage with lighting provided by EIA's 2003 CBECS.^{xxix} Table 8.2.14 presents the estimated shares of commercial lamp purchases by ownership category of commercial building space.

Table 8.2.14 Estimated Share of Lamp Purchases by Ownership Category in the Commercial Sector

Ownership Category	Percent
Property Owners and Managers	22.3
Industrial Firms	10.1
Commercial Firms	54.8
Government	12.8

Source: 2003 CBECS.

* The share of total square footage occupied by property owners is actually 44.6%. However, in some of these buildings, the tenants purchase lamps. DOE assumes that this is the case for half of the square footage occupied by property owners. DOE allocates this quantity among the other categories in proportion to their shares of total square footage.

Table 8.2.15 presents the distribution of lamp ownership for the commercial and industrial lighting sectors.

Table 8.2.15 Lamp Ownership by Sector

Sector	Property Owners %	Industrial Companies %	Commercial Companies %	Government %
Industrial	0	100	0	0
Commercial	22.3	10.1	54.8	12.8

Sources: Commercial, CBECS; Industrial, DOE estimate.

DOE estimates discount rate distributions for the different sectors as a weighted average of the distributions for the different ownership types. The resulting weighted average discount rates are 7.6 percent for the industrial sector and 7.0 percent for the commercial sector. Table 8.2.16 summarizes the weighted average discount rates in all three sectors.

Table 8.2.16 Average Discount Rate by Sector

Sector	Discount Rate %
Industrial	7.6
Commercial	7.0
Residential	5.6

8.2.9 Effective Date of Standard

The effective date is the date when a new standard becomes operative, i.e., the date by which lamp manufacturers must manufacture products that comply with the standard. DOE's publication of a final rule in this standards rulemaking is scheduled for completion in June 2009. The effective date of any new energy conservation standards for these lamps must be 3 years after the final rule is published, (42 U.S.C. 6295(i)(3) and (i)(5)), which will be June 2012. DOE calculates the LCCs for all consumers as if each would purchase a new product in the year the standard takes effect. However, DOE bases the cost of the equipment on the most recent available data; all dollar values are expressed in 2007\$.

8.2.10 Residual Value

The residual value represents the remaining value of a lamp or a ballast from the end of the period of analysis to the end of the service life of the lamp or ballast. Since the analysis period is based on the lifetime of the longest-lived baseline lamp, DOE assumes lamps with lifetimes shorter than the analysis period are replaced. To account for the remaining value of these lamps (with remaining life) to the consumer, the LCC model applies this residual value as a “credit” at the end of the analysis period, and discounts it back to the start of the analysis period. This methodology is shown in Equation 8.1, where DOE presents how it incorporates residual value into its LCC calculation. The equation for residual value is as follows:

$$RV = IC \cdot \left\{ \frac{SL - [P_{Analysis} - (n \cdot SL)]}{SL} \right\} + DC \cdot \left\{ \frac{P_{Analysis} - (n \cdot SL)}{SL} \right\} \quad \text{Eq. 8.8}$$

where

<i>IC</i>	=	total installed cost of the product,
<i>n</i>	=	the number of replacements within the analysis period,
<i>SL</i>	=	the service life of the product,
<i>DC</i>	=	disposal cost, and
<i>P_{Analysis}</i>	=	the analysis period.

DOE determines the residual value of the product by linearly prorating the replacement cost (i.e., total installed cost) and the disposal cost by the remaining service life. For example, consider a \$10 4-foot GSFL that has a service life of 5 years and a disposal cost of \$0.40 and is used to replace a baseline lamp that has a service life of 3 years in the commercial sector. Since the baseline lamp defines the analysis period, DOE would calculate the residual value of the lamp design as $(2 \div 5) \times \$10 + (3 \div 5) \times \0.40 , or \$4.24. Thus, the residual value in equation 8.8 would be \$4.24, and that value would be discounted back to the start of the time period of analysis. This equation is used for both lamps and ballasts installed by consumers.

8.3 PAYBACK PERIOD INPUTS

8.3.1 Definition

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

The equation for PBP is:

$$PBP = \frac{\Delta IC}{\Delta OC} \quad \text{Eq. 8.9}$$

where

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

PBPs are expressed in years. PBPs greater than the life of the product mean that the increased total installed cost of the more efficacious product is not recovered in reduced operating costs over the lifetime of that product. Because all lamp designs and lamp-and-ballast designs in the LCC and PBP analyses save energy and thus yield a positive ΔOC , PBPs that are negative indicate that the total installed cost of the equipment that meets the more efficacious EL is less than that of the baseline.

8.3.2 Rebuttable Presumption Payback Period

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

DOE’s lamp test procedures measure the rate of light output per unit power consumption of a lamp (i.e., lumens per watt; lm/W) rather than a measurement of energy consumption (i.e., a measurement over a duration or operating time period). Therefore, to calculate energy savings for the rebuttable presumption payback period, one would need to multiply the rate of power consumption of a lamp times the usage profile of that lamp. For IRL, energy savings calculations in the LCC and PBP analyses use both the relevant test procedures as well as the relevant usage profile. Because DOE calculates payback periods in a methodology consistent with the rebuttable presumption test for IRL in the LCC and payback period analyses, DOE is not performing a stand-alone rebuttable presumption analysis for IRL, as it is already embodied in the LCC and PBP analyses. For GSFL, DOE believes that the rate of energy consumption of the lamp-and-ballast system is a more accurate measure of real world power consumption than the rate of power consumption of the lamp as measured on a reference ballast as prescribed by

the test procedure.² Because calculations of energy savings in the LCC are based under real-world conditions, DOE will also rely on standard payback periods for GSFL.

8.3.3 Inputs

The data inputs to PBP are the total installed cost of the product to the customer for each EL and the annual (first year) operating costs for each EL. The inputs to the total installed cost are the final product price and the installation cost. The inputs to the operating costs are the lamp or lamp-and-ballast system power rating, annual operating hours, and electricity cost. The PBP uses the same inputs as the LCC calculation described in section 8.2, except that electricity price trends are not required. Since the PBP is a “simple” (undiscounted) PBP, the required electricity cost is only for the year in which a new energy conservation standard is to take effect—in this case, 2012. The electricity price DOE uses in the PBP calculation for electricity cost is the price projected for 2012, expressed in 2007\$, but not discounted to 2007. DOE does not use discount rates in the PBP calculation.

8.4 LAMP PURCHASING EVENTS

DOE designs the LCC and PBP analyses for this rulemaking around scenarios where consumers need to replace a lamp; DOE collectively refers to these as, “lamp purchasing events.” Each of these events may present the consumer with a different set of lamp or lamp-and-ballast designs and therefore a different set of LCC savings for a certain EL. For GSFL, DOE has identified five possible scenarios under which consumers would purchase a lamp and potentially be affected by an energy conservation standard. These scenarios are: 1) lamp failure, 2) standards-induced retrofit, 3) ballast failure, 4) ballast retrofit and 5) new construction/renovation.

For IRL, due to the fact that there is no ballast involved, the scenarios for the incandescent lamp product classes are simply a lamp failure or new construction and renovation. For GSFL, the five lamp purchasing events are described in more detail below. In addition to these descriptions, Table 8.4.1 and Table 8.4.2 summarize the lamp purchasing events considered in this analysis.

- Lamp failure: This event reflects a scenario in which a lamp either fails (spot re-lamping) or is about to fail (group re-lamping) and must be replaced. In the absence of the energy conservation standard, generally, an identical lamp would have been installed as a replacement. However, under an energy conservation standard, a standards-compliant lamp that operates on the existing ballast is required. Thus, the first consumer response to a lamp failure is expected to be a simple lamp replacement with the same type of lamp. A second

² For example, T8 lamps which are often operated on high-frequency electronic ballasts, may be tested and measured on a line-frequency (60 Hz) reference ballast using DOE’s test procedure, resulting in different performance characteristics than this lamp would exhibit in the field, operated on an electronic ballast.

response occurs for owners of T12 systems. Unlike T8 or T5 lamps, there are some standard levels that a T12 lamp cannot meet. Therefore, at certain levels, these users would be required to purchase a new lamp-and-ballast system to meet the standard. At these certain levels, DOE believes the scenario of a lamp failure and lamp-and-ballast replacement would be more common in the residential sector. For the commercial and industrial sectors, DOE believes consumers would primarily experience the standards-induced retrofit event described below.

- **Standards-induced retrofit:** This is a scenario in which an increase in the energy conservation standard induces end-users to retrofit both lamps and ballasts (whereas, in the base case, they would otherwise have installed only a lamp). This lamp purchasing event only applies to users with T12 lamps because, unlike T8 or T5 lamps, there are certain standard levels that a T12 lamp cannot meet. This event contemplates a scenario where users, under an energy conservation standard, can no longer purchase a T12 replacement lamp for their T12 ballast. In the commercial and industrial sectors, DOE assumes consumers in the standards case choose to change their lamps and ballasts early, instead of waiting for their T12 lamps to fail. Therefore, in the standards case, a lamp-and-ballast purchase would occur at the beginning of the analysis, before the average lamp being replaced has failed. In the base case in the commercial and industrial sectors, DOE assumes a uniform age distribution of T12 lamps. Based on this age distribution, the average T12 lamp is halfway through its lifetime. Therefore, consumers in the base case purchase a lamp after the average T12 lamp has died (i.e., after it has lived through the second half of its lifetime). In the residential sector, DOE assumes that consumers will not proactively retrofit their T12 systems before their T12 lamps fail. Therefore in the base case consumers purchase a lamp and standards case consumers purchase a lamp-and-ballast system at the beginning of the analysis period.
- **Ballast failure:** This is a scenario in which the installed ballast has failed. DOE recognizes that energy conservation standards set by the 2000 Ballast Rule and the Energy Policy Act of 2005 (EPACT 2005), Pub. L. 109-58, are effective in 2010 and may affect the types of systems available to the consumer to purchase. These standards ban the sale of most magnetic 4-foot medium bipin and 8-foot single pin slimline ballasts. Therefore, in the base case, users who had a magnetic or electronic T12 ballast would be expected to replace it with an electronic T12 ballast and corresponding standards-compliant lamp (if available). The regulations from the 2000 Ballast Rule, however, allow the continued sale of magnetic cold temperature ballasts, which operate a portion of the installed base of 8-foot T12 recessed double contact HO lamps. The 2000 Ballast Rule also includes exceptions for magnetic ballasts in the residential sector. Therefore, failed 8-foot recessed double contact HO ballasts as well as residential ballasts and fixtures are expected to be replaced with magnetic ballasts or fixtures containing magnetic ballasts. Users in all product classes who had a T8 or T5 ballast fail would be expected to replace it with a T8 or T5 ballast and corresponding standards-compliant lamp. However, in the standards case, end-users would select a standards-compliant lamp-ballast combination such that the system light output never drops below 10 percent of the baseline system.
- **Ballast retrofit:** DOE applies this event only to T12 users because the majority of ballasts that are currently being retrofitted are T12 lamp-and-ballast systems, according to industry

experts. Absent standards, end-users may decide to retrofit their old ballasts and lamps to save energy. With standards, end-users will also retrofit their old lamp-and-ballast systems, but with standards-compliant lamps. DOE assumes that end-users continue to use the existing fixture and replace only the ballast. Because the spatial layout in the building space is a constrained by the number of fixtures, light output of the replacement lamp-and-ballast system never drops below 10 percent of the baseline system.

- **New construction and renovation:** This lamp purchasing event encompasses all the new fixture installations where the lighting design will be completely new or can be completely changed. This scenario is only applicable to those baseline lamps that are usually used in new construction and renovation (4-foot T8 medium bipin lamps, 4-foot T12 medium bipin lamps in the residential sector, 4-foot T5 miniature bipin SO and HO lamps, 8-foot single pin slimline T8 lamps, and 8-foot recessed double contact HO T12 lamps). DOE assumes that 4-foot T8 medium bipin lamps with electronic ballasts would be chosen during the new construction and renovation event for the 4-foot T12 medium bipin baseline in the residential sector. During new construction and renovation, the spatial layout of fixtures in the building space is not constrained to any previous configuration. Because new fixtures can be installed, consumers could install a lamp-and-ballast system that would not maintain the light output of the baseline system. For instance, if light output of the standards case system is lower than the base case system, consumers can increase the number of standards case lamp-and-ballast systems installed in the building by a certain percentage to maintain the light output of base case lamp-and-ballast systems.

Table 8.4.1 through Table 8.4.3 outline the events and actions taken by stakeholders in response to those events both in the base case and the standards case.

Table 8.4.1 Framework of Event-Type Scenarios for T12 Lamps

Event	Base Case Action	Standards Case Action
Type 1. Lamp Failure	(a) Installs a T12 lamp.	Installs a lower-wattage, higher efficacy lamp such that the system light output never drops below 10 percent of the baseline system.
	(b) Installs a T12 lamp.	Installs a T12 or T8 electronic ballast and lamp such that the system light output never drops below 10 percent of the baseline system.
Type 2. Standards-Induced Retrofit	Replace lamp halfway through analysis period in the commercial and industrial sectors. * Replace lamp at the beginning of the analysis period in the residential sector.	Installs a new T12 or T8 electronic ballast and lamp such that the system light output never drops below 10 percent of the baseline system.
Type 3. Ballast Failure	Installs a T12 ballast and lamps in the existing fixture. HO ballasts and residential ballasts are magnetic, while other ballasts are electronic.	Installs a new T12 or T8 ballast and lamps such that the system light output never drops below 10 percent of the baseline system.
Type 4. Ballast Retrofit	Installs a T8 electronic ballast and lamps in the existing fixture.	Installs a new T12 or T8 ballast and lamps such that the system light output never drops below 10 percent of the baseline system.
Type 5. New Construction and Renovation	For the 4-foot medium bipin product class, installs a new T8 system in the commercial and industrial sectors; installs a new T8 or T12 medium bipin system in the residential sector. For the 8-foot recessed double contact HO product class, installs a new T12 or T8 system.	Installs a new T12 or T8 system such that the system light output never drops below 10 percent of the baseline system. Light output can be maintained through spacing.

* Note: Event Type 2 represents a standards-induced retrofit where lamps are substituted before the end of their lifetime in the commercial and industrial sectors. DOE assumed that lamps lived to half of their average lifetime when substituted under this scenario.

Table 8.4.2 Framework of Event-Type Scenarios for T8 Lamps

Event	Base Case Action	Standards Case Action
Type 1. Lamp Failure	Installs a lamp.	Installs a lower-wattage, higher efficacy lamp such that the system light output never drops below 10 percent of the baseline system.
Type 3. Ballast Failure	Installs a T8 electronic ballast and lamps in the existing fixture.	Installs new T8 ballast and lamps such that the system light output never drops below 10 percent of the baseline system.
Type 5. New Construction and Renovation	Installs a new T8 system.	Installs a new T8 system such that the system light output never drops below 10 percent of the baseline system. Light output can be maintained through spacing.

Table 8.4.3 Framework of Event-Type Scenarios for T5 Lamps

Event	Base Case Action	Standards Case Action
Type 1. Lamp Failure	Installs a lamp.	Installs a lower-wattage, higher efficacy lamp such that the system light output never drops below 10 percent of the baseline system.
Type 3. Ballast Failure	Installs a T5 electronic ballast and lamps in the existing fixture.	Installs a new T5 ballast and lamps such that the system light output never drops below 10 percent of the baseline system.
Type 5. New Construction and Renovation	Installs a new T5 system.	Installs a new T5 system such that the system light output never drops below 10 percent of the baseline system. Light output can be maintained through spacing.

8.5 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

This section presents LCC results for each lamp and lamp-and-ballast design DOE considers. This section uses the terms “positive LCC savings” and “negative LCC savings.” When a standard results in “positive LCC savings,” the life cycle cost of the standards-compliant lamp is less than the life-cycle cost of the baseline lamp and the consumer benefits. A consumer is adversely affected when a standard results in “negative LCC savings” (i.e., when the life-cycle cost of the standards-compliant lamp is higher than the life-cycle cost of the baseline lamp).

As stated earlier, DOE conducts a series of LCC calculations for each baseline lamp. For GSFL, DOE considers lamp-only substitutions as well as lamp-and-ballast substitutions. For IRL, DOE considers lamp-only substitutions. In all cases, DOE considers only designs that save energy and which maintain light output above a maximum 10 percent decrease from the baseline lamp or system.

All replacement options are designed around lamp purchasing events. For GSFL, DOE identified five possible events where consumers would purchase a lamp, and therefore be affected by an energy conservation standard. These events are lamp failure, standards-induced retrofit, ballast failure, ballast retrofit, and renovation/new construction. The LCC spreadsheet

calculates the LCC impacts for each of these scenarios separately. Examining the impacts on each scenario separately allows one to view the results of many subgroup populations in the LCC analysis.

8.5.1 Results for General Service Fluorescent Lamps

DOE is analyzing five representative product classes for GSFL: 4-foot medium bipin $\leq 4,500\text{K}$, 8-foot single pin slimline $\leq 4,500\text{K}$, 8-foot recessed double contact HO $\leq 4,500\text{K}$, 4-foot T5 miniature bipin standard output $\leq 4,500\text{K}$, and 4-foot T5 miniature bipin high output $\leq 4,500\text{K}$. This section presents all of the results for each of these representative product classes and for each baseline lamp. The results are presented by lamp purchasing event, by sector, and by whether a consumer purchases a lamp or a lamp and ballast, both of which influence the LCC and PBP results.

For each product class and baseline lamp, a summary of the most pertinent results in the LCC analysis is also presented. In this summary, DOE indicates why the LCC savings and installed price increases are not presented for certain ELs under certain baselines and events with an acronym. For instance, DOE assumed that consumers wish to purchase systems or lamp replacements with a lumen output within 10 percent of their baseline system output. In some cases, the only available replacement options produce less light than this. Thus, certain replacement options are considered unsuitable substitutions. These options are marked with “LL” (less light) in the LCC results summary tables. In some cases, when consumers who currently own a T12 system need to replace their lamps, no T12 energy saving lamp replacements are available. In these cases, in order to save energy, the consumers must switch to other options, such as a T8 lamp and appropriate ballast. These cases are marked with “NER” (no energy-saving replacement) in tables.

Because some baseline lamps already meet higher efficacy levels (*e.g.*, the baseline 32W 4-foot T8 medium bipin lamp achieves EL2), LCC savings at the levels below the baseline are zero. In these cases, “BAE” (baseline above efficacy level) is listed in the tables to indicate that the consumer makes the same purchase decision in the standards-case as they do in the base-case. Also, not all lamp purchase events apply for all baseline lamps or efficacy levels. For example, DOE assumed that the standards-induced retrofit event does not apply to the 32W T8 system, because it is already the most efficacious 4-foot medium bipin GSFL system. For these events, an “EN/A” (event not applicable) exists in the table. Finally, because LCC savings are not relevant when no energy conservation standard is established, “N/A” (not applicable) exists in the LCC savings column for the baseline system.

DOE is also presenting the installed prices of the lamp-and-ballast systems in order to compare the up-front costs that consumers must bear when purchasing baseline or standards-case systems. For example, the installed price results for a lamp replacement in response to a lamp failure event (Event IA) only include the lamp purchase price and lamps installation costs. On the other hand, the ballast failure event (Event III) and the new construction/renovation event (Event IV) include the purchase and installation costs for lamps and a ballast for the baseline and standards-case systems. This is because the occurrences of these events require the purchase of new lamps and ballasts in all cases.

8.5.1.1 Product Class: Four-foot medium bipin $\leq 4,500\text{K}$

For the 4-foot medium bipin $\leq 4,500\text{K}$ product class in the commercial sector, DOE analyzes three baseline lamps: 40W T12, 34W T12, and 32W T8. In the residential sector, DOE only analyzes the 4-foot 40W T12 medium bipin lamp as a baseline for this product class as DOE believes this is the predominant lamp type installed in that sector. For each baseline lamp, DOE analyzes multiple lamp substitutions with each lamp substitution corresponding to the efficacy levels. Table 8.5.1 presents the findings of the LCC and PBP analyses on the first 4-foot medium bipin baseline GSFL. This table presents the LCC and PBP results for the 40W T12 baseline lamp operating in the commercial sector. Key inputs consist of using *AEO2008* reference case electricity prices, an analysis period of 5.5 years, and medium-range lamp and ballast prices.

The results for Event IA (Lamp Failure) show that the LCC of the baseline 4-foot 40W T12 medium bipin lamp on a magnetic ballast is higher than the LCC of the 34W T12 on a magnetic ballast that meets EL3. Any EL beyond EL3 for this baseline would require a lamp-and-ballast replacement. As discussed in the engineering analysis (Chapter 5), although a 4-foot 34W T12 medium bipin lamp is often considered a reduced wattage replacement of the 40W T12 lamp, there were no lamp options that emitted enough lumens to fall within 10 percent of the baseline system lumens. The highest efficacy 34W T12 lamp replacement is shown below. The system light output of this lamp-and-ballast design is 10.3 percent less than that of the baseline system. The same drop in lumen output is also exhibited by the 34WT12 lamp on an electronic ballast of the same BF.

Because no 4-foot T12 medium bipin lamps would be standards compliant at EL4 and EL5, consumers with T12 ballasts who are confronted with a lamp failure beyond EL3 would be forced to retrofit their ballasts and instead purchase a T8 system. The LCC savings and incremental costs related to this action can be seen under the standards induced retrofit event (Event II). At EL4 and EL5, consumers who are forced to retrofit their ballast would achieve positive LCC savings; however, they would also incur an incremental installed price (baseline installed price minus standards-case installed price) greater than \$49.30 per system. In particular, 4-foot 40W T12 medium bipin consumers who retrofit would obtain the greatest LCC savings at EL4 and EL5 by retrofitting to an electronically-ballasted 32W T8 system.

Event III represents consumers who are already faced with replacing both a lamp and a ballast. The baseline ballast for this event is assumed to be an electronic T12, since the ballast standards from the 2000 Ballast Rule and EPACT 2005 would be effective in 2010. In order to save energy with similar lumen output at EL1 and EL2, consumers would purchase a higher-efficacy 4-foot 40W T12 medium bipin with a lower-BF ballast. These choices result in negative LCC savings. However, under such a standard, 40W T12 consumers would be able to achieve positive LCC savings under a ballast failure scenario by purchasing systems at EL4 and EL5. Similar to the standards-induced retrofit, at EL4 and EL5 consumers are forced to purchase T8 systems. Those who purchase a 4-foot 32W T8 medium bipin lamp generally achieve the highest LCC savings. Consumers prompted by this event would experience positive LCC savings if they purchase a high efficacy 4-foot T8 medium bipin lamp on an electronic ballast at all ELs.

Event IV represents consumers who are already planning on retrofitting a 4-foot T12 medium bipin system with a T8 system. The baseline system for this event is assumed to be a T8 system. To save energy with similar lumen output at EL3, consumers could purchase a 34W T12 with an electronic ballast. However, those who purchase a 32W T8 lamp generally achieve the highest LCC savings.

Table 8.5.1 LCC and PBP Results for a Three-Lamp 4-Foot 40W T12 Medium Bipin System Operating in the Commercial Sector

Event	Response	Efficacy Level	Rated Lamp Efficacy	Design Option ³	LCC	LCC Savings	Installed Price	Operating Cost Savings (Start Year)	Payback Period	% Mean Lumens from Baseline
			<i>lms/W</i>		\$	\$	\$	\$	<i>yrs</i>	%
Event I: Lamp Failure	Baseline	Baseline	78.0	41 W T12 & 0.95 BF Mag	202.20	0.00	13.96	0.00	N/A	0.0
	A: Lamp Replacement	EL3	91.2	34 W T12 & 0.88 BF Mag	179.93	22.27	25.13	7.08	1.6	-10.3
	B: Lamp & Ballast Replacement	EL1	80.5	41 W T12 & 0.88 BF Elec	208.46	-6.25	72.51	7.20	8.1	-3.5
		EL1	82.9	41 W T12 & 0.87 BF Elec	209.18	-6.97	77.16	7.43	8.5	-2.7
		EL2	86.2	32.5 W T8 & 1.18 BF Elec	208.81	-6.60	65.11	5.29	9.7	8.7
		EL2	87.8	41 W T12 & 0.87 BF Elec	209.44	-7.24	77.45	7.43	8.5	3.3
		EL3	91.2	34 W T12 & 0.88 BF Elec	186.83	15.37	77.06	12.60	5.0	-10.3
		EL3	90.8	32.5 W T8 & 1 BF Elec	188.76	13.44	68.21	10.66	5.1	-1.0
		EL4	92.3	32.5 W T8 & 0.88 BF Elec	167.37	34.83	60.96	14.24	3.3	-8.3
		EL4	93.8	30.4 W T8 & 1 BF Elec	179.72	22.48	69.49	13.06	4.3	-2.0
		EL4	93.0	26.6 W T8 & 1.18 BF Elec	175.10	27.11	73.25	13.92	4.3	1.4
		EL5	95.4	32.5 W T8 & 0.88 BF Elec	168.76	33.44	62.52	14.24	3.4	-6.2
		EL5	96.0	28.4 W T8 & 1 BF Elec	172.99	29.22	68.89	15.18	3.6	-6.4

³ Throughout the GSFL results tables, descriptions such as “40W T12 & 0.95 BF Mag” are used. The first term (e.g., 40W) is the rated wattage, the second is the lamp diameter (e.g., T12), the third is the ballast factor of the ballast (e.g., 0.95 BF), and the fourth is the ballast type (e.g., “Mag” for Magnetic or “Elec” for Electronic).

Table 8.5.1 LCC and PBP Results for a Three-Lamp 4-Foot 40W T12 Medium Bipin System Operating in the Commercial Sector (continued)

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Mean Lumens from Baseline %
Event II: Standards Induced Retrofit	Baseline	Baseline	78.0	41 W T12 & 0.95 BF Mag	195.38	0.00	13.96	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL1	80.5	41 W T12 & 0.88 BF Elec	209.82	-14.43	74.82	7.20	8.5	-3.5
		EL1	82.9	41 W T12 & 0.87 BF Elec	210.54	-15.16	79.46	7.43	8.8	-2.7
		EL2	86.2	32.5 W T8 & 1.18 BF Elec	210.17	-14.79	67.42	5.29	10.1	8.7
		EL2	87.8	41 W T12 & 0.87 BF Elec	210.80	-15.42	79.76	7.43	8.9	3.3
		EL3	91.2	34 W T12 & 0.88 BF Elec	188.19	7.19	79.37	12.60	5.2	-10.3
		EL3	90.8	32.5 W T8 & 1 BF Elec	190.13	5.26	70.52	10.66	5.3	-1.0
		EL4	92.3	32.5 W T8 & 0.88 BF Elec	168.73	26.65	63.26	14.24	3.5	-8.3
		EL4	93.8	30.4 W T8 & 1 BF Elec	181.08	14.30	71.80	13.06	4.4	-2.0
		EL4	93.0	26.6 W T8 & 1.18 BF Elec	176.46	18.92	75.56	13.92	4.4	1.4
		EL5	95.4	32.5 W T8 & 0.88 BF Elec	170.12	25.26	64.83	14.24	3.6	-6.2
EL5	96.0	28.4 W T8 & 1 BF Elec	174.35	21.04	71.19	15.18	3.8	-6.4		
Event III: Ballast Failure	Baseline	Baseline	78.0	41 W T12 & 0.88 BF Elec	201.84	0.00	65.89	0.00	N/A	-7.4*
	Lamp & Ballast Replacement	EL1	80.5	41 W T12 & 0.87 BF Elec	207.47	-5.63	72.51	0.23	28.9	-4.6
		EL1	82.9	41 W T12 & 0.87 BF Elec	209.18	-7.34	77.16	0.23	49.2	-2.7
		EL2	87.8	41 W T12 & 0.87 BF Elec	209.44	-7.60	77.45	0.23	50.5	3.3
		EL3	91.2	34 W T12 & 0.88 BF Elec	186.83	15.01	77.06	5.40	2.1	-10.3
		EL3	90.8	32.5 W T8 & 1 BF Elec	188.76	13.08	68.21	3.46	0.7	-1.0
		EL4	92.3	32.5 W T8 & 0.88 BF Elec	167.37	34.47	60.96	7.04	0.0	-8.3
		EL4	93.8	30.4 W T8 & 1 BF Elec	179.72	22.12	69.49	5.85	0.6	-2.0
		EL4	93.0	26.6 W T8 & 1.18 BF Elec	175.10	26.74	73.25	6.72	1.1	1.4
		EL5	95.4	32.5 W T8 & 0.88 BF Elec	168.76	33.08	62.52	7.04	0.0	-6.2
		EL5	96.0	28.4 W T8 & 1 BF Elec	172.99	28.85	68.89	7.98	0.4	-6.4

* Comparative lumens are sometimes non-zero for baseline T12 electronic systems under Event Type 3 and 4 (ballast failure and retrofit) because the lumen package is compared to a system with a T12 magnetic ballast. DOE chose to compare these systems for these events because it recognizes that though federal regulations will prohibit the use of magnetic ballasts, future purchasers may still seek the current lumen package delivered by current T12 magnetic systems.

Table 8.5.1 LCC and PBP Results for a Three-Lamp 4-Foot 40W T12 Medium Bipin System Operating in the Commercial Sector (continued)

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i>yrs</i>	% Mean Lumens from Baseline %
Event IV: Ballast Retrofit	Baseline	Baseline/EL2	86.2	32.5 W T8 & 1.18 BF Elec	210.17	0.00	67.42	0.00	N/A	8.7
	Lamp & Ballast Replacement	EL3	91.2	34 W T12 & 0.88 BF Elec	188.19	21.98	79.37	7.31	1.6	-10.3
		EL3	90.8	32.5 W T8 & 1 BF Elec	190.13	20.04	70.52	5.37	0.6	-1.0
		EL4	92.3	32.5 W T8 & 0.88 BF Elec	168.73	41.44	63.26	8.96	0.0	-8.3
		EL4	93.8	30.4 W T8 & 1 BF Elec	181.08	29.08	71.80	7.77	0.6	-2.0
		EL4	93.0	26.6 W T8 & 1.18 BF Elec	176.46	33.71	75.56	8.63	0.9	1.4
		EL5	95.4	32.5 W T8 & 0.88 BF Elec	170.12	40.05	64.83	8.96	0.0	-6.2
EL5	96.0	28.4 W T8 & 1 BF Elec	174.35	35.82	71.19	9.89	0.4	-6.4		

Table 8.5.2 presents the findings of the LCC and PBP analyses on a second baseline 4-foot medium bipin GSFL. This table presents the LCC and PBP results for the 4-foot 34W T12 medium bipin baseline lamp operating in the commercial sector. Key inputs consist of using *AEO2008* reference case electricity prices, an analysis period of 5.5 years, and medium-range lamp and ballast prices.

For the 4-foot 34W T12 medium bipin baseline, when commercial consumers are confronted with a lamp failure in the base case, they purchase the 34W T12 baseline lamp as a lamp replacement on their magnetic T12 ballast. As this is the lowest-wattage commercially-available T12 lamp, there are no energy-saving lamp replacement options for this system. Because there are no energy-saving lamp replacement options for a 34W T12 lamp, Event IA is not shown. However, consumers do have the option to purchase higher-efficacy 34W T12 lamps, resulting in no energy-savings and an installed price increase ranging from \$3.70 to \$13.91.

For Event II, the standards-induced retrofit event, consumers retrofitting to a 4-foot 34W T12 medium bipin lamp on an electronic T12 ballast experience negative LCC savings. However, under such a standard, consumers would also be able to achieve positive savings by purchasing EL2, EL3, EL4, and EL5 T8 systems with either a higher-efficacy 32W T8 lamp or other reduced-wattage lamps. Because no 4-foot T12 medium bipin lamps would be standards-compliant at EL4 and EL5, consumers with T12 ballasts who are confronted with a lamp failure at these levels would be forced to retrofit their ballasts and instead purchase a T8 system. The incremental installed prices associated with this forced retrofit are greater than \$51.62 per system.

For the 4-foot 34W T12 medium bipin baseline, when commercial consumers are confronted with a ballast failure (Event III) in the base case, they purchase the 34W T12 baseline lamps and a 0.88 ballast factor electronic ballast. In order to save energy with similar lumen output at EL1 and EL2, consumers would purchase a higher-efficacy 34W T12 with a lower-BF ballast. In addition, at EL3, consumers may purchase a 4-foot 34W T12 medium bipin lamp with a lower-BF ballast as well. However, these choices result in negative LCC savings. However, under such a standard, 34W T12 consumers can achieve positive LCC savings under a ballast failure scenario by purchasing systems at EL4 and EL5. Similar to the standards-induced retrofit, at EL4 and EL5, consumers would be forced to purchase T8 systems. Those who purchase the reduced-wattage 4-foot 25W and 28W T8 medium bipin lamps achieve the highest LCC savings.

Event IV represents consumers who are already planning on retrofitting a 4-foot T12 medium bipin system with a T8 system. The baseline system for this event is assumed to be a T8 system. To save energy with similar lumen output at EL3, consumers could purchase a 34W T12 with an electronic ballast. However, those who purchase a 32W T8 lamp generally achieve the highest LCC savings.

Table 8.5.2 LCC and PBP Results for a Three-Lamp 4-Foot 34W T12 Medium Bipin System Operating in the Commercial Sector

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i>yrs</i>	% Mean Lumens from Baseline
Event I: Lamp Failure	Baseline	Baseline	77.9	34 W T12 & 0.88 BF Mag	168.95	0.00	11.22	0.00	N/A	0.0
	B: Lamp & Ballast Replacement	EL1	82.4	34 W T12 & 0.88 BF Elec	179.54	-10.59	66.84	5.52	10.1	7.0
		EL2	85.3	34 W T12 & 0.86 BF Elec	184.59	-15.64	73.87	5.97	10.5	10.9
		EL2	86.2	32.5 W T8 & 0.88 BF Elec	165.69	3.25	57.43	7.16	6.5	9.6
		EL3	90.8	32.5 W T8 & 0.78 BF Elec	155.94	13.01	60.53	10.14	4.9	4.4
		EL3	91.2	34 W T12 & 0.86 BF Elec	184.86	-15.91	77.06	5.97	11.0	18.5
		EL4	92.3	32.5 W T8 & 0.75 BF Elec	150.65	18.29	60.96	11.04	4.5	5.6
		EL4	93.8	30.4 W T8 & 0.78 BF Elec	148.82	20.13	61.81	12.09	4.2	3.3
		EL4	93.0	26.6 W T8 & 0.88 BF Elec	139.70	29.25	65.57	14.00	3.9	2.2
		EL5	95.4	32.5 W T8 & 0.71 BF Elec	146.90	22.05	62.52	12.23	4.2	2.3
EL5	96.0	28.4 W T8 & 0.78 BF Elec	143.80	25.14	61.20	13.82	3.6	-1.3		
Event II: Standards Induced Retrofit	Baseline	Baseline	77.9	34 W T12 & 0.88 BF Mag	163.39	0.00	11.22	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL1	82.4	34 W T12 & 0.88 BF Elec	180.90	-17.51	69.15	5.52	10.5	7.0
		EL2	85.3	34 W T12 & 0.86 BF Elec	185.95	-22.56	76.18	5.97	10.9	10.9
		EL2	86.2	32.5 W T8 & 0.88 BF Elec	167.06	-3.67	59.74	7.16	6.8	9.6
		EL3	90.8	32.5 W T8 & 0.78 BF Elec	157.30	6.09	62.84	10.14	5.1	4.4
		EL3	91.2	34 W T12 & 0.86 BF Elec	186.22	-22.83	79.37	5.97	11.4	18.5
		EL4	92.3	32.5 W T8 & 0.75 BF Elec	152.01	11.37	63.26	11.04	4.7	5.6
		EL4	93.8	30.4 W T8 & 0.78 BF Elec	150.18	13.21	64.11	12.09	4.4	3.3
		EL4	93.0	26.6 W T8 & 0.88 BF Elec	141.06	22.33	67.88	14.00	4.0	2.2
		EL5	95.4	32.5 W T8 & 0.71 BF Elec	148.26	15.13	64.83	12.23	4.4	2.3
EL5	96.0	28.4 W T8 & 0.78 BF Elec	145.17	18.22	63.51	13.82	3.8	-1.3		

Table 8.5.2 LCC and PBP Results for a Three-Lamp 4-Foot 34W T12 Medium Bipin System Operating in the Commercial Sector (continued)

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i>yrs</i>	% Mean Lumens from Baseline
Event III: Ballast Failure	Baseline	Baseline	77.9	34 W T12 & 0.88 BF Elec	175.85	0.00	63.15	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL1	82.4	34 W T12 & 0.86 BF Elec	177.56	-1.72	66.84	0.46	8.1	4.5
		EL2	85.3	34 W T12 & 0.86 BF Elec	184.59	-8.74	73.87	0.46	23.4	10.9
		EL2	86.2	32.5 W T8 & 0.88 BF Elec	165.69	10.15	57.43	1.64	0.0	9.6
		EL3	90.8	32.5 W T8 & 0.78 BF Elec	155.94	19.91	60.53	4.63	0.0	4.4
		EL3	91.2	34 W T12 & 0.86 BF Elec	184.86	-9.01	77.06	0.46	30.4	18.5
		EL4	92.3	32.5 W T8 & 0.75 BF Elec	150.65	25.20	60.96	5.52	0.0	5.6
		EL4	93.8	30.4 W T8 & 0.78 BF Elec	148.82	27.03	61.81	6.58	0.0	3.3
		EL4	93.0	26.6 W T8 & 0.88 BF Elec	139.70	36.15	65.57	8.48	0.3	2.2
		EL5	95.4	32.5 W T8 & 0.71 BF Elec	146.90	28.95	62.52	6.72	0.0	2.3
EL5	96.0	28.4 W T8 & 0.78 BF Elec	143.80	32.04	61.20	8.30	0.0	-1.3		
Event IV: Ballast Retrofit	Baseline	Baseline/EL2	86.2	32.5 W T8 & 0.88 BF Elec	167.06	0.00	59.74	0.00	N/A	9.6
	Lamp & Ballast Replacement	EL3	90.8	32.5 W T8 & 0.78 BF Elec	157.30	18.55	62.84	2.99	0.0	4.4
		EL4	92.3	32.5 W T8 & 0.75 BF Elec	152.01	23.83	63.26	3.88	0.0	5.6
		EL4	93.8	30.4 W T8 & 0.78 BF Elec	150.18	25.67	64.11	4.94	0.2	3.3
		EL4	93.0	26.6 W T8 & 0.88 BF Elec	141.06	34.78	67.88	6.84	0.7	2.2
		EL5	95.4	32.5 W T8 & 0.71 BF Elec	148.26	27.59	64.83	5.08	0.3	2.3
		EL5	96.0	28.4 W T8 & 0.78 BF Elec	145.17	30.68	63.51	6.66	0.1	-1.3

Table 8.5.3 presents the findings of an LCC and PBP analyses on a third baseline 4-foot medium bipin GSFL. This table presents the LCC and PBP results for the 4-foot 32W T8 medium bipin baseline lamp operating in the commercial sector. Key inputs consist of using *AEO2008* reference case electricity prices, an analysis period of 5.5 years, and medium-range lamp and ballast prices.

For the 4-foot 32W T8 medium bipin baseline, commercial consumers purchase either the 32W T8 baseline lamp (under lamp failure) or the 32W T8 baseline lamp and an electronic 0.88 BF ballast (under ballast failure). Event I (Lamp Failure) displays results for consumers who must replace a baseline lamp with a higher efficacy lamp. For this event, installing reduced wattage lamps is the only opportunity for energy savings. At EL4, consumers who purchase 4-foot 30W T8 medium bipin lamps achieve lower LCC savings than those who purchase 25W T8 lamps. At EL5, the only reduced-wattage lamp replacement option (the 28W T8) achieves positive LCC savings.

When confronted with a ballast failure or new construction purchase (Events III and V), consumers who would have purchased the 4-foot 32W T8 medium bipin baseline system, would achieve positive LCC savings at EL3 by purchasing higher-efficacy 32W T8 lamps on a lower-BF ballast. At EL4, these consumers could obtain the greater LCC savings by purchasing an electronically-ballasted 25W T8 system on a 0.88 BF ballast. However, there is a 6.7 percent decrease in mean lumens from the baseline. At EL5, they achieve highest savings by purchasing the 4-foot 32W T8 medium bipin lamp on a lower-BF ballast.

Table 8.5.3 LCC and PBP Results for a 3-Lamp 4-foot 32W T8 Medium Bipin System Operating in the Commercial Sector

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Mean Lumens from Baseline %
Event I: Lamp Failure	Baseline	Baseline/EL2	86.2	32.5 W T8 & 0.88 BF Elec	138.86	0.00	11.97	0.00	N/A	0.0
	A: Lamp Replacement	EL4	93.8	30.4 W T8 & 0.88 BF Elec	133.97	4.89	16.35	2.15	2.0	6.3
		EL4	93.0	26.6 W T8 & 0.88 BF Elec	112.87	25.99	20.11	6.84	1.2	-6.7
		EL5	96.0	28.4 W T8 & 0.88 BF Elec	128.17	10.69	15.74	4.06	0.9	1.6
Event III: Ballast Failure	Baseline	Baseline/EL2	86.2	32.5 W T8 & 0.88 BF Elec	165.69	0.00	57.43	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL3	90.8	32.5 W T8 & 0.78 BF Elec	155.94	9.76	60.53	2.99	1.0	-4.7
		EL4	92.3	32.5 W T8 & 0.75 BF Elec	150.65	15.04	60.96	3.88	0.9	-3.6
		EL4	93.8	30.4 W T8 & 0.78 BF Elec	148.82	16.88	61.81	4.94	0.9	-5.7
		EL4	93.0	26.6 W T8 & 0.88 BF Elec	139.70	25.99	65.57	6.84	1.2	-6.7
		EL5	95.4	32.5 W T8 & 0.75 BF Elec	152.04	13.65	62.52	3.88	1.3	-1.4
		EL5	96.0	28.4 W T8 & 0.88 BF Elec	155.01	10.69	61.20	4.06	0.9	1.6
Event V: New Construction and Renovation	Baseline	Baseline/EL2	86.2	32.5 W T8 & 0.88 BF Elec	167.06	0.00	59.74	0.00	N/A	0.0
	New Lamp & Ballast Purchase	EL3	90.8	32.5 W T8 & 0.78 BF Elec	157.30	9.76	62.84	2.99	1.0	-4.7
		EL4	92.3	32.5 W T8 & 0.75 BF Elec	152.01	15.04	63.26	3.88	0.9	-3.6
		EL4	93.8	30.4 W T8 & 0.78 BF Elec	150.18	16.88	64.11	4.94	0.9	-5.7
		EL4	93.0	26.6 W T8 & 0.88 BF Elec	141.06	25.99	67.88	6.84	1.2	-6.7
		EL5	95.4	32.5 W T8 & 0.75 BF Elec	153.40	13.65	64.83	3.88	1.3	-1.4
		EL5	96.0	28.4 W T8 & 0.88 BF Elec	156.37	10.69	63.51	4.06	0.9	1.6

Table 8.5.4 summarizes the range of commercial sector LCC results for the 4-foot medium bipin product class. Only the most relevant events under each baseline lamp are shown. As discussed above, an EL at or above EL4 would induce the replacement of T12 magnetic ballasts with electronic T8 ballasts, as no 4-foot 40W or 34W T12 medium bipin lamps can meet these ELs. For all baseline lamps, and for all ballast replacement events, there are design options with positive LCC savings at ELs above EL2.

Table 8.5.4 Summary of the LCC Results for a Three-Lamp 4-Foot Medium Bipin System Operating in the Commercial Sector

Baseline	Efficacy Level	LCC Savings 2007\$			Installed Price 2007\$		
		Event IA: Lamp Replacement*	Event II: Standards- Induced Retrofit (Lamp and Ballast Replacement)*	Event III: Ballast Failure*†	Event IA: Lamp Replacement	Event II: Standards- Induced Retrofit (Lamp and Ballast Replacement)	Event III: Ballast Failure†
40 Watt T12	Base-line	N/A	N/A	N/A	13.96	13.96	65.89
	EL1	LL	EN/A	-7.34 to -5.63	LL	EN/A	72.51 to 77.16
	EL2	LL	EN/A	-7.60	LL	EN/A	77.45
	EL3	22.27	EN/A	13.08 to 15.01	25.13	EN/A	68.21 to 77.06
	EL4	NR	14.30 to 26.65	22.12 to 34.47	NR	63.26 to 75.56	60.96 to 73.25
	EL5	NR	21.04 to 25.26	28.85 to 33.08	NR	64.83 to 71.19	62.52 to 68.89
34 Watt T12	Base-line	N/A	N/A	N/A	11.22	11.22	63.15
	EL1	NER	-17.51	-1.72	14.91	69.15	66.84
	EL2	NER	-22.56 to -3.67	-8.74 to 10.15	21.94	59.74 to 76.18	57.43 to 73.87
	EL3	NER	-22.83 to 6.09	-9.01 to 19.91	25.13	62.84 to 79.37	60.53 to 77.06
	EL4	NR	11.37 to 22.33	25.20 to 36.15	NR	63.26 to 67.88	60.96 to 65.57
	EL5	NR	15.13 to 18.22	28.95 to 32.04	NR	63.51 to 64.83	61.20 to 62.52
32 Watt T8	Base-line	N/A	N/A	N/A	11.97	11.97	57.43
	EL1	BAE	EN/A	BAE	BAE	EN/A	BAE
	EL2	BAE	EN/A	BAE	BAE	EN/A	BAE
	EL3	NER	EN/A	9.76	NER	EN/A	60.53
	EL4	4.89 to 25.99	EN/A	15.04 to 25.99	16.35 to 20.11	EN/A	60.96 to 65.57
	EL5	10.69	EN/A	10.69 to 13.65	15.74	EN/A	61.20 to 62.52

†For 32 Watt T8 baseline, includes Event V (New Construction and Renovation).

*Analysis period is 5.5 years.

N/A: Not Applicable; NER: No Energy-Saving Replacement; LL: Available Options Produce Less Light; EN/A: Event Not Applicable; BAE: Baseline Above Efficacy Level; NR: No Replacement

Table 8.5.5 and Table 8.5.6 present the findings of the LCC and PBP analyses on the 4-foot 40W T12 medium bipin baseline GSFL for the residential sector. The results in were generated using high operating hours (of 1,210 hours per year), allowing the lamp failure event to occur. The 4-foot 40W T12 medium bipin lamp is the only baseline for the residential sector GSFL analysis due to the rarity of 34W T12 and 32W T8 lamps in the residential sector. Key inputs consist of using *AEO2008* reference case electricity prices and medium-range lamp and ballast prices. The analysis period is 15 years for Event III and 2.5 years for Events IA (Lamp Replacement) and IB (Lamp & Ballast Replacement). As discussed in section 8.2.3.1, operating hours for Event III are average operating hours for GSFL (789 hours/year) while operating hours for Event IA and IB are higher than average (1,210 hours/year).

In general, residential consumers replacing their lamps experience negative LCC savings. For Event IA (Lamp Replacement), there are no energy saving replacement lamp options for the 4-foot 40W T12 medium bipin residential system. DOE recognizes that not all consumers can use a 4-foot 34W T12 medium bipin lamp on a residential magnetic low power factor ballast because not all ballasts are designated to operate this lamp. However, in its review of manufacturer literature, DOE identified several low power factor residential magnetic ballasts that are designated to operate the 34W T12 lamp. Therefore, DOE considers this event applicable for some residential consumers. These consumers are adversely impacted by EL3 when replacing only a failed lamp (Event IA). The reduced-wattage 4-foot 34W T12 medium bipin lamp, while more efficacious than the baseline, does not save enough energy to offset its increased purchase price within the 2.5 year analysis period, leading to negative LCC savings.

Event IB (Lamp & Ballast Replacement) differs from a standards-induced retrofit because DOE assumes that Event IB occurs as a response to a lamp failure. In both Event IB and a standards-induced retrofit, a consumer purchases only a lamp in the base case and a lamp-and-ballast in the standards case. However, DOE assumes that residential consumers will not proactively replace their 4-foot T12 medium bipin systems before their T12 lamp fails; thus, the standards-induced retrofit event does not apply to the residential sector. At EL4 and EL5, consumers must purchase a 4-foot T8 medium bipin system as T12 lamps do not meet these ELs. At all ELs in Event IB, the available system options do not save enough energy to offset their increased purchase price of the lamp and ballast in 2.5 years, leading to negative LCC savings.

In the case of Event III (Ballast Failure), residential consumers purchase a magnetic 4-foot T12 medium bipin system in the base case and an electronic or magnetic T12 system or electronic T8 system in the standards case. At all standard levels, LCC savings are positive. The least positive LCC savings occurs at EL3 where a consumer purchases a magnetic T12 system with a 34W lamp in the standards case. LCC savings are the most positive when a consumer purchases a 28W T8 system at EL4.

For Event V (New Construction and Renovation), DOE assumes that the baseline residential sector lamp will be a 4-foot T8 medium bipin lamp and electronic ballast. In the standards case, only one T12 option exists, which is a reduced wattage electronically ballasted T12 at EL3. At all other standard levels, only T8s can be purchased. All standard levels applicable to Event V produce positive LCC savings for consumers. LCC savings are the most positive when a consumer purchases a 4-foot 28W T8 medium bipin lamp at EL5.

Table 8.5.5 LCC and PBP Results for a Two-Lamp 4-Foot 40W T12 Medium Bipin System Operating in the Residential Sector Using High Operating Hours

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Mean Lumens from Baseline %
Event I: Lamp Failure	Baseline	Baseline	76.8	41 W T12 & 0.68 BF Mag	25.43	0.00	3.98	0.00	N/A	0.0
	A: Lamp Replacement	EL3	91.2	34 W T12 & 0.66 BF Mag	30.85	-5.42	12.46	1.36	6.2	-5.3
	B: Lamp and Ballast Replacement	EL1	80.5	41 W T12 & 0.65 BF Elec	32.68	-7.25	51.00	1.63	28.9	0.3
		EL1	82.4	34 W T12 & 0.85 BF Elec	32.80	-7.37	47.22	1.09	39.8	7.5
		EL1	82.9	41 W T12 & 0.65 BF Elec	33.59	-8.16	54.10	1.63	30.8	2.3
		EL2	85.3	34 W T12 & 0.75 BF Elec	29.88	-4.45	51.90	2.99	16.0	0.7
		EL2	86.2	32.5 W T8 & 0.78 BF Elec	30.05	-4.62	48.64	2.49	17.9	1.1
		EL2	87.8	41 W T12 & 0.65 BF Elec	33.65	-8.22	54.29	1.63	30.9	8.6
		EL3	91.2	34 W T12 & 0.66 BF Mag	35.33	-9.90	57.95	1.36	39.8	-5.3
		EL3	91.2	34 W T12 & 0.75 BF Elec	30.51	-5.08	54.03	2.99	16.8	7.6
		EL3	90.8	32.5 W T8 & 0.75 BF Elec	30.02	-4.59	50.71	2.77	16.9	4.5
		EL4	92.3	32.5 W T8 & 0.75 BF Elec	30.10	-4.67	50.99	2.77	17.0	9.9
		EL4	93.8	30.4 W T8 & 0.75 BF Elec	29.54	-4.11	51.56	3.09	15.4	3.4
		EL4	93.0	26.6 W T8 & 0.78 BF Elec	28.21	-2.78	54.07	4.01	12.5	-5.7
		EL5	95.4	32.5 W T8 & 0.71 BF Elec	29.56	-4.13	52.03	3.15	15.3	6.4
EL5	96.0	28.4 W T8 & 0.78 BF Elec	28.93	-3.50	51.16	3.31	14.2	2.7		

Table 8.5.6 LCC and PBP Results for a Two-Lamp 4-Foot 40W T12 Medium Bipin System Operating in the Residential Sector Using Average Operating Hours

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Mean Lumens from Baseline %
Event III: Ballast Failure	Baseline	Baseline	76.8	41 W T12 & 0.68 BF Mag	110.70	0.00	49.47	0.00	N/A	0.0
	Lamp and Ballast Replacement	EL1	80.5	41 W T12 & 0.65 BF Elec	101.74	8.96	51.00	1.06	1.4	0.3
		EL1	82.4	34 W T12 & 0.85 BF Elec	101.46	9.24	47.22	0.71	0.0	7.5
		EL1	82.9	41 W T12 & 0.65 BF Elec	104.84	5.87	54.10	1.06	4.4	2.3
		EL2	85.3	34 W T12 & 0.75 BF Elec	93.90	16.81	51.90	1.95	1.3	0.7
		EL2	86.2	32.5 W T8 & 0.78 BF Elec	93.82	16.88	48.64	1.62	0.0	1.1
		EL2	87.8	41 W T12 & 0.65 BF Elec	105.03	5.67	54.29	1.06	4.5	8.6
		EL3	91.2	34 W T12 & 0.66 BF Mag	110.44	0.27	57.95	0.89	9.6	-5.3
		EL3	91.2	34 W T12 & 0.75 BF Elec	96.02	14.68	54.03	1.95	2.3	7.6
		EL3	90.8	32.5 W T8 & 0.75 BF Elec	94.08	16.63	50.71	1.81	0.7	4.5
		EL4	92.3	32.5 W T8 & 0.75 BF Elec	94.36	16.34	50.99	1.81	0.8	9.9
		EL4	93.8	30.4 W T8 & 0.75 BF Elec	92.85	17.85	51.56	2.02	1.0	3.4
		EL4	93.0	26.6 W T8 & 0.78 BF Elec	89.47	21.24	54.07	2.61	1.8	-5.7
		EL5	95.4	32.5 W T8 & 0.71 BF Elec	92.98	17.72	52.03	2.05	1.3	6.4
EL5	96.0	28.4 W T8 & 0.78 BF Elec	91.05	19.66	51.16	2.16	0.8	2.7		
Event V: New Construction and Renovation	Baseline	Baseline/EL2	86.2	32.5 W T8 & 0.88 BF Elec	102.17	0.00	50.95	0.00	N/A	0.0
	New Lamp & Ballast Purchase	EL3	91.2	34 W T12 & 0.75 BF Elec	98.33	3.84	56.34	0.93	45.4	-5.6
		EL3	90.8	32.5 W T8 & 0.78 BF Elec	98.20	3.97	53.02	0.61	63.9	-4.7
		EL4	92.3	32.5 W T8 & 0.78 BF Elec	98.48	3.69	53.30	0.61	64.3	0.2
		EL4	93.8	30.4 W T8 & 0.78 BF Elec	96.65	5.52	53.87	0.85	46.7	-5.7
		EL4	93.0	26.6 W T8 & 0.88 BF Elec	96.08	6.09	56.37	1.17	36.4	-6.7
		EL5	95.4	32.5 W T8 & 0.75 BF Elec	97.71	4.46	54.34	0.79	50.8	-1.4
EL5	96.0	28.4 W T8 & 0.78 BF Elec	93.35	8.82	53.46	1.15	34.4	-10.0		

Table 8.5.7 and Table 8.5.8 present a summary of the residential sector LCC results for the 4-foot 40W T12 medium bipin baseline GSFL. Only the most relevant events are shown. As discussed above, an EL at or above EL4 would induce the replacement of T12 magnetic ballasts with electronic T8 ballasts, as no 4-foot 40W or 34W T12 medium bipin lamps can meet these ELs. There are design options with positive LCC savings at ELs above EL2 for Event III. However, no LCC savings are possible under Event I, the lamp failure event.

Table 8.5.7 Summary of the LCC Results for a Two-Lamp 4-Foot 40W T12 Medium Bipin System Operating in the Residential Sector Using High Operating Hours

Baseline	Efficacy Level	LCC Savings 2007\$		Installed Price 2007\$	
		Event IA: Lamp Replacement*	Event IB: Lamp and Ballast Replacement*	Event IA: Lamp Replacement	Event IB: Lamp and Ballast Replacement
40 Watt T12	Baseline	N/A	N/A	3.98	3.98
	EL1	LL	EN/A	LL	EN/A
	EL2	LL	EN/A	LL	EN/A
	EL3	-5.42	EN/A	12.46	EN/A
	EL4	NR	-4.67 to -2.78	NR	50.99 to 54.07
EL5	NR	-4.13 to -3.50	NR	51.16 to 52.03	

*Analysis period is 2.5 years.
N/A: Not Applicable; LL: Available Options Produce Less Light; EN/A: Event Not Applicable; NR: No Replacement

Table 8.5.8 Summary of the LCC Results for a Two-Lamp 4-Foot 40W T12 Medium Bipin System Operating in the Residential Sector Using Average Operating Hours

Baseline	Efficacy Level	LCC Savings 2007\$	Installed Price 2007\$
		Event III: Ballast Failure*	Event III: Ballast Failure
40 Watt T12	Baseline	N/A	49.47
	EL1	5.87 to 9.24	47.22 to 54.10
	EL2	5.67 to 16.88	48.64 to 54.29
	EL3	0.27 to 16.63	50.71 to 57.95
	EL4	16.34 to 21.24	50.99 to 54.07
EL5	17.72 to 19.66	51.16 to 52.03	

*Analysis period is 15 years.
N/A: Not Applicable

8.5.1.2 Product Class: 4-foot T5 miniature bipin high output $\leq 4,500\text{K}$

Table 8.5.9 presents the results for an electronically ballasted 4-foot T5 miniature bipin HO baseline system operating in the commercial sector. For this baseline, the analysis period is 3.9 years. Other key inputs consist of using *AEO2008* reference case electricity prices and medium-range lamp and ballast prices. DOE analyzes multiple lamp substitutions with each lamp substitution corresponding to the efficacy level requirement.

Negative LCC savings exist for Events I and III. For these events, the standards case 4-foot T5 miniature bipin high output lamps do not save enough energy to offset their increased installed price. However, positive LCC savings exist for Event V. For this event, consumers can change the physical layout of their system in order to match the mean lumen output of the baseline system. Because the 4-foot T5 miniature bipin HO baseline halophosphor lamps have such poor lumen maintenance compared to the 800-series lamps LCC savings for the new construction event are high. In this event, the selection of a reduced wattage 4-foot T5 miniature bipin HO lamp gives the most positive LCC savings. Table 8.5.10 shows a summary table of LCC results for the 4-foot T5 miniature bipin HO baseline system.

Table 8.5.9 LCC and PBP Results for a Two-Lamp 4-Foot 54W T5 Miniature Bipin High Output System Operating in the Commercial Sector

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i>yrs</i>	% Mean Lumens from Baseline %
Event I: Lamp Failure	Baseline	Baseline	76.6	53.8 W T5 & 1 BF Elec	124.80	0.00	10.44	0.00	N/A	0.0
	A: Lamp Replacement	EL1	98.0	51 W T5 & 1 BF Elec	128.22	-3.42	19.85	0.90	10.5	59.4
Event III: Ballast Failure	Baseline	Baseline	76.6	53.8 W T5 & 1 BF Elec	156.34	0.00	69.03	0.00	N/A	0.0
	Lamp and Ballast Replacement	EL1	98.0	51 W T5 & 1 BF Elec	159.76	-3.42	78.44	0.90	10.5	59.4
Event V: New Construction and Renovation	Baseline	Baseline	76.6	53.8 W T5 & 1 BF Elec	157.58	0.00	71.33	0.00	N/A	0.0
	New Lamp & Ballast Purchase	EL1	92.9	53.8 W T5 & 1 BF Elec	101.98	55.60	76.36	13.37	0.0	0.0
		EL1	98.0	51 W T5 & 1 BF Elec	100.98	56.60	80.74	13.93	0.0	0.0

Table 8.5.10 Summary of the LCC Results for a Two-Lamp 4-Foot 54W T5 Miniature Bipin High Output System Operating in the Commercial Sector

Baseline	Efficacy Level	LCC Savings 2007\$		Installed Price 2007\$	
		Event IA: Lamp Replacement*	Event V: New Construction/Renovation*	Event IA: Lamp Replacement	Event V: New Construction/Renovation
54 Watt T5	Baseline	N/A	N/A	10.44	71.33
	EL1	-3.42	55.60 to 56.60	19.85	76.36 to 80.74

*Analysis period is 3.9 years.
N/A: Not Applicable; NER: No Energy-Saving Replacement

8.5.1.3 Product Class: 4-foot T5 miniature bipin standard output $\leq 4,500\text{K}$

Table 8.5.11 presents the results for an electronically ballasted 4-foot T5 miniature bipin standard output baseline system operating in the commercial sector. The analysis period is 5.5 years. Other key inputs consist of using *AEO2008* reference case electricity prices and medium-range lamp and ballast prices. DOE analyzes multiple lamp substitutions with each lamp substitution corresponding to EL efficacy level requirements.

Positive LCC savings exist at all of the ELs analyzed for all events. For Event V, consumers can change the physical layout of their system in order to match the mean lumen output of the baseline system. Because the 4-foot T5 miniature bipin SO baseline halophosphor lamps have such poor lumen maintenance compared to the 800-series lamps, LCC savings for the new construction event are high. For Events III and V, the selection of a reduced wattage 4-foot T5 miniature bipin SO lamp gives the most positive LCC savings. Table 8.5.12 shows a summary table of LCC results for the 4-foot T5 miniature bipin standard output baseline system.

Table 8.5.11 LCC and PBP Results for a Two-Lamp 4-Foot 28W T5 Miniature Bipin Standard Output System Operating in the Commercial Sector

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i>yrs</i>	% Mean Lumens from Baseline %
Event I: Lamp Failure	Baseline	Baseline	86.0	27.8 W T5 & 1.15 BF Elec	112.64	0.00	9.39	0.00	N/A	0.0
	A: Lamp Replacement	EL2	111.5	26 W T5 & 1.15 BF Elec	111.42	1.22	14.86	1.09	5.0	58.9
Event III: Ballast Failure	Baseline	Baseline	86.0	27.8 W T5 & 1.15 BF Elec	146.58	0.00	66.89	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL1	104.3	27.8 W T5 & 0.95 BF Elec	136.60	9.98	70.65	3.19	1.2	31.3
		EL2	109.7	27.8 W T5 & 0.9 BF Elec	135.36	11.22	72.85	3.99	1.5	35.5
		EL2	111.5	26 W T5 & 0.9 BF Elec	126.33	20.26	72.36	5.51	1.0	24.4
Event V: New Construction and Renovation	Baseline	Baseline	86.0	27.8 W T5 & 1.15 BF Elec	147.95	0.00	69.20	0.00	N/A	0.0
	New Lamp & Ballast Purchase	EL1	104.3	27.8 W T5 & 0.95 BF Elec	105.10	42.84	72.96	8.11	0.0	0.0
		EL2	109.7	27.8 W T5 & 0.9 BF Elec	100.92	47.03	75.16	9.19	0.0	0.0
		EL2	111.5	26 W T5 & 0.9 BF Elec	102.68	45.27	74.67	9.10	0.0	0.0

Table 8.5.12 Summary of the LCC Results for a Two-Lamp 4-Foot 28W T5 Miniature Bipin Standard Output System Operating in the Commercial Sector

Baseline	Efficacy Level	LCC Savings 2007\$		Installed Price 2007\$	
		Event IA: Lamp Replacement*	Event V: New Construction/Renovation*	Event IA: Lamp Replacement	Event V: New Construction/Renovation
28 Watt T5	Baseline	N/A	N/A	9.39	69.20
	EL1	NER	42.84	13.15	72.96
	EL2	1.22	45.27 to 47.03	14.86	74.67 to 75.16

*Analysis period is 5.5 years.

N/A: Not Applicable; NER: No Energy-Saving Replacement

8.5.1.4 Product Class: 8-Foot single pin slimline $\leq 4,500\text{K}$

For the 8-foot single pin slimline $\leq 4,500\text{K}$ product class, DOE is analyzing three baseline lamps: 75W T12, 60W T12, and 59W T8. For each baseline lamp, DOE analyzes multiple lamp substitutions with each lamp substitution corresponding to the efficacy level requirements.

Table 8.5.13 presents the findings of the LCC and PBP analyses on the first baseline 8-foot single pin slimline GSFL. This table presents the LCC and PBP results for the 8-foot 75W T12 single pin slimline baseline lamp operating in the commercial sector. Key inputs consist of using *AEO2008* reference case electricity prices, an analysis period of 4 years, and medium-range lamp and ballast prices.

The results for Event IA show that the LCC of the baseline 8-foot 75W T12 single pin slimline lamp on a magnetic ballast is higher than the LCC of the 60W T12 on a magnetic ballast that meets EL3. Any EL above EL3 for this baseline would require a lamp-and-ballast replacement. As discussed in the engineering analysis (Chapter 5), although a 8-foot 60W T12 single pin slimline lamp is often considered a reduced wattage replacement of the 75W T12 lamp, there are no lamp options with a CCT of 4,100K that emit enough lumens to fall within 10 percent of the baseline system lumens. Shown below is the highest efficacy 4,100K, 8-foot 60W T12 single pin slimline lamp replacement. The system light output of this lamp-and-ballast design is 13 percent less than that of the baseline system. Note that any standard level beyond EL3 would likely require consumers to replace their 8-foot T12 single pin slimline lamps and ballasts with T8 systems, since no T12 lamp currently meets the efficacy requirements of EL4 and EL5.

The results for Event II show that consumers who replace a functioning 8-foot 75W T12 single pin slimline lamp on a magnetic ballast with a high efficacy T8 lamp that meets EL5 on an electronic ballast benefit from lower LCCs at EL5 while incurring an incremental installed price of \$78.96 per system. The EL4 lamp available in this event does not produce sufficient light output, so DOE assumes that at standard level EL4, 8-foot 75W T12 single pin slimline consumers would retrofit to the EL5 59W T8 and 0.88 ballast factor ballast. All ELs greater than EL3 can only be met by replacing the baseline ballast.

Event III represents consumers who are already faced with replacing both a lamp and a ballast. The baseline ballast for this event is assumed to be an electronic T12, since the ballast standards from the 2000 Ballast Rule and EPACKT 2005 would be effective in 2010. In the standards case, 8-foot 75W T12 single pin slimline consumers can purchase more-efficacious 75W T12 lamps and lower-ballast-factor ballasts at EL1 and EL2. However, these systems do not save enough energy over their lifetimes to offset their increased installed price. The systems at EL3 and EL4 do not produce sufficient lumen output in comparison to the baseline system, so DOE assumes that 8-foot 75W T12 single pin slimline consumers encountering ballast failures would purchase the EL5 59W T8 and 0.88 ballast factor ballast at standard levels EL3 and EL4. At standard levels EL4 and EL5, only T8 systems are available. At EL5, 8-foot 75W T12 single pin slimline consumers can achieve positive LCC savings by purchasing the T8 system.

For Event IV, the ballast retrofit event, the baseline is assumed to be an electronically ballasted T8 system. Only one replacement lamp system option (at EL5) can match the lumen output of the baseline system for Event IV. This option gives positive LCC savings.

Table 8.5.13 LCC and PBP Results for a Two-Lamp 8-Foot 75W T12 Single Pin Slimline System Operating in the Commercial Sector

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i>yrs</i>	% Mean Lumens from Baseline %	
Event I: Lamp Failure	Baseline	Baseline	85.6	75 W T12 & 0.94 BF Mag	197.83	0.00	16.16	0.00	N/A	0.0	
	A: Lamp Replacement	EL3	97.5	60.5 W T12 & 0.88 BF Mag	161.10	36.73	19.43	10.80	0.3	-13.1	
	B: Lamp & Ballast Replacement	Baseline	Baseline	85.6	75 W T12 & 0.94 BF Mag	197.83	0.00	16.16	0.00	N/A	0.0
		EL1	EL1	87.3	75 W T12 & 0.85 BF Elec	209.59	-11.76	95.31	8.77	9.0	-5.7
		EL2	EL2	92.0	75 W T12 & 0.85 BF Elec	205.60	-7.76	97.21	8.77	9.2	-2.5
		EL3	EL3	94.8	60.1 W T8 & 1.18 BF Elec	224.86	-27.03	109.87	2.72	34.4	9.0
	EL5	EL5	101.5	60.1 W T8 & 0.88 BF Elec	176.56	21.28	92.82	15.24	5.0	-8.1	
Event II: Standards Induced Retrofit	Baseline	Baseline	85.6	75 W T12 & 0.94 BF Mag	189.05	0.00	16.16	0.00	N/A	0.0	
	Lamp & Ballast Replacement	EL1	EL1	87.3	75 W T12 & 0.85 BF Elec	210.63	-21.58	97.62	8.77	9.3	-5.7
		EL2	EL2	92.0	75 W T12 & 0.85 BF Elec	206.64	-17.58	99.52	8.77	9.5	-2.5
		EL3	EL3	94.8	60.1 W T8 & 1.18 BF Elec	225.90	-36.85	112.18	2.72	35.3	9.0
	EL5	EL5	101.5	60.1 W T8 & 0.88 BF Elec	177.60	11.45	95.12	15.24	5.2	-8.1	
Event III: Ballast Failure	Baseline	Baseline	85.6	75 W T12 & 0.88 BF Elec	205.00	0.00	88.94	0.00	N/A	-6.4	
	Lamp & Ballast Replacement	EL1	EL1	87.3	75 W T12 & 0.85 BF Elec	209.59	-4.59	95.31	1.01	6.3	-5.7
		EL2	EL2	92.0	75 W T12 & 0.85 BF Elec	205.60	-0.59	97.21	1.01	8.2	-2.5
		EL5	EL5	101.5	60.1 W T8 & 0.88 BF Elec	176.56	28.45	92.82	7.48	0.5	-8.1
Event IV: Ballast Retrofit	Baseline	Baseline/EL3	94.8	60.1 W T8 & 1.18 BF Elec	225.90	0.00	112.18	0.00	N/A	9.0	
	Lamp & Ballast Replacement	EL5	EL5	101.5	60.1 W T8 & 0.88 BF Elec	177.60	48.30	95.12	12.52	0.0	-8.1

Table 8.5.14 presents the findings of LCC and PBP analyses on a second baseline 8-foot single pin slimline GSFL. This table presents the LCC and PBP results for the 8-foot 60W T12 single pin slimline baseline lamp operating in the commercial sector. Key inputs consist of using *AEO2008* reference case electricity prices, an analysis period of 4 years, and medium-range lamp and ballast prices.

Because consumers of 8-foot 60W T12 single pin slimline lamps do not have access to any energy-saving T12 replacement lamps in response to a lamp failure, Event IA is not shown. However, at EL1, EL2 and EL3 consumers could still purchase the 8-foot 60W T12 single pin slimline baseline lamp for their magnetic ballast. Although these T12 lamps do not save energy, the installed price increase of purchasing these lamps ranges from \$4.88 to \$8.30.

Event II represents consumers who respond to higher lamp standards by retrofitting a functioning 8-foot 60W T12 single pin slimline system with a new lamp and ballast that save energy. For example, to save energy at EL2 and EL3, consumers of 8-foot 60W T12 single pin slimline lamps can choose to retrofit to T12 or T8 systems with electronic ballasts. 8-foot 60W T12 single pin slimline consumers cannot achieve positive LCC savings with any of the systems available for a standards-induced retrofit at any EL, although they would save energy. Standard levels EL4 and EL5 also force 8-foot T12 lamps single pin slimline from the market, requiring consumers to retrofit to T8 systems and incur installed price increases of at least \$82.08.

Event III represents consumers who are already faced with replacing both a lamp and a ballast. The baseline ballast for this event is assumed to be an electronic T12, since the ballast standards from the 2000 Ballast Rule and EPACT 2005 would be effective in 2010. At standard levels EL2 and EL3, consumers could purchase more-efficient 8-foot 60W T12 single pin slimline lamps and lower-ballast-factor electronic ballasts when faced with a ballast failure. However, consumers cannot save enough energy with these systems to achieve positive LCC savings. Instead, they can purchase the 8-foot T8 single pin slimline systems on electronic ballasts available at EL4 and EL5 to achieve positive LCC savings. In the face of standard levels EL4 and EL5, T12 systems are eliminated from the market. Consumers can achieve the greatest positive LCC savings with a 8-foot 57W T8 single pin slimline lamp on a 0.78 ballast factor electronic ballast at EL5, while consumers purchasing the 8-foot 59W T8 single pin slimline lamp on a 0.78 ballast factor electronic ballast at EL4 achieve the least positive LCC savings.

Three replacement lamp system options exist in response to Event IV. For this event, consumers obtain the most positive LCC savings at EL5 with an electronically ballasted 8-foot 57W T8 single pin slimline lamp system.

Table 8.5.14 LCC and PBP Results for a Two-Lamp 8-Foot 60W T12 Single Pin Slimline System Operating in the Commercial Sector

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i>yrs</i>	% Mean Lumens from Baseline %
Event I: Lamp Failure	Baseline	Baseline/EL1	87.6	60.5 W T12 & 0.88 BF Mag	156.15	0.00	11.33	0.00	N/A	0.0
	B: Lamp & Ballast Replacement	EL2	92.6	60.5 W T12 & 0.85 BF Elec	173.61	-17.46	88.79	6.41	12.1	6.7
		EL3	97.5	60.5 W T12 & 0.85 BF Elec	172.73	-16.58	92.21	6.41	12.6	13.5
		EL3	94.8	60.1 W T8 & 0.88 BF Elec	173.06	-16.91	86.72	4.45	17.0	10.0
		EL4	98.2	60.1 W T8 & 0.78 BF Elec	163.65	-7.50	91.10	8.62	9.3	3.2
		EL5	101.8	57 W T8 & 0.78 BF Elec	161.01	-4.86	91.48	7.93	10.1	3.6
		EL5	101.5	60.1 W T8 & 0.78 BF Elec	162.77	-6.62	92.82	8.62	9.5	10.1
Event II: Standards Induced Retrofit	Baseline	Baseline/EL1	87.6	60.5 W T12 & 0.88 BF Mag	149.79	0.00	11.33	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL2	92.6	60.5 W T12 & 0.85 BF Elec	174.65	-24.86	91.10	6.41	12.4	6.7
		EL3	97.5	60.5 W T12 & 0.85 BF Elec	173.77	-23.98	94.52	6.41	13.0	13.5
		EL3	94.8	60.1 W T8 & 0.88 BF Elec	174.10	-24.31	89.03	4.45	17.5	10.0
		EL4	98.2	60.1 W T8 & 0.78 BF Elec	164.69	-14.90	93.41	8.62	9.5	3.2
		EL5	101.8	57 W T8 & 0.78 BF Elec	162.05	-12.26	93.79	7.93	10.4	3.6
		EL5	101.5	60.1 W T8 & 0.78 BF Elec	163.81	-14.02	95.12	8.62	9.7	10.1

Table 8.5.14 LCC and PBP Results for a Two-Lamp 8-Foot 60W T12 Single Pin Slimline System Operating in the Commercial Sector (continued)

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i> yrs</i>	% Mean Lumens from Baseline %
Event III: Ballast Failure	Baseline	Baseline/EL1	87.6	60.5 W T12 & 0.88 BF Elec	171.12	0.00	84.11	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL2	92.6	60.5 W T12 & 0.85 BF Elec	173.61	-2.48	88.79	1.01	4.6	6.7
		EL3	97.5	60.5 W T12 & 0.85 BF Elec	172.73	-1.61	92.21	1.01	8.0	13.5
		EL4	98.2	60.1 W T8 & 0.78 BF Elec	163.65	7.47	91.10	3.22	2.2	3.2
		EL5	101.8	57 W T8 & 0.78 BF Elec	161.01	10.12	91.48	2.53	2.9	3.6
		EL5	101.5	60.1 W T8 & 0.78 BF Elec	162.77	8.35	92.82	3.22	2.7	10.1
Event IV: Ballast Retrofit	Baseline	Baseline/EL3	94.8	60.1 W T8 & 0.88 BF Elec	174.10	0.00	89.03	0.00	N/A	10.0
	Lamp & Ballast Replacement	EL4	98.2	60.1 W T8 & 0.78 BF Elec	164.69	9.41	93.41	4.17	1.0	3.2
		EL5	101.8	57 W T8 & 0.78 BF Elec	162.05	12.06	93.79	3.48	1.4	3.6
		EL5	101.5	60.1 W T8 & 0.78 BF Elec	163.81	10.29	95.12	4.17	1.5	10.1

Table 8.5.15 presents the findings of LCC and PBP analyses on 8-foot single pin slimline GSFL. This table presents the LCC and PBP results for the 8-foot 59W T8 single pin slimline baseline lamp operating in the commercial sector. Key inputs consist of using *AEO2008* reference case electricity prices, an analysis period of 4 years, and medium-range lamp and ballast prices.

The results for Event IA show that the LCC of the baseline 8-foot 59W T8 single pin slimline lamp on an electronic ballast is higher than the LCC of the 8-foot 57W or 55W T8 single pin slimline lamps on an electronic ballast that meets EL5. Consumers purchasing these lamps achieve positive LCC savings and incur installed price increases ranging from \$3.95 to \$4.76. Those purchasing the 8-foot 55W T8 single pin slimline lamp achieve the greatest positive LCC savings.

Event III represents consumers who must replace both a lamp and a ballast in response to a ballast failure. In response to a ballast failure, consumers of 8-foot 59W T8 single pin slimline lamps can purchase the baseline 59W T8 system at EL1 through EL3. The available system at EL4 is a 8-foot 59W T8 single pin slimline lamp on a 0.85 ballast factor electronic ballast, and consumers purchasing this system would achieve negative LCC savings. At EL5, 8-foot 59W T8 single pin slimline consumers could purchase 59W, 57W, or 55W T8 systems on electronic ballasts and achieve positive LCC savings. Those purchasing the 8-foot 55W T8 single pin slimline system would achieve the greatest positive LCC savings, while those purchasing the 57W T8 system would achieve the least positive LCC savings. Results are identical for Event V.

Table 8.5.16 summarizes the range of results for the 8-foot single pin slimline product class. Only the most relevant events under each baseline lamp are shown.

Table 8.5.15 LCC and PBP Results for a Two-Lamp 8-Foot 59W T8 Single Pin Slimline System Operating in the Commercial Sector

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i>yrs</i>	% Mean Lumens from Baseline %
Event I: Lamp Failure	Baseline	Baseline/EL3	94.8	60.1 W T8 & 0.88 BF Elec	139.71	0.00	12.74	0.00	N/A	0.0
	A: Lamp Replacement	EL5	101.8	57 W T8 & 0.88 BF Elec	133.23	6.48	17.50	1.79	2.7	6.2
		EL5	103.6	55 W T8 & 0.88 BF Elec	129.29	10.42	16.68	3.64	1.1	5.6
Event III: Ballast Failure	Baseline	Baseline/EL3	94.8	60.1 W T8 & 0.88 BF Elec	173.06	0.00	86.72	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL4	98.2	60.1 W T8 & 0.85 BF Elec	173.30	-0.24	91.10	1.25	3.5	2.2
		EL5	101.8	57 W T8 & 0.85 BF Elec	164.91	8.15	91.48	2.30	2.1	2.6
		EL5	101.5	60.1 W T8 & 0.78 BF Elec	162.77	10.29	92.82	4.17	1.5	0.1
		EL5	103.6	55 W T8 & 0.88 BF Elec	162.64	10.42	90.67	3.64	1.1	5.6
Event V: New Construction and Renovation	Baseline	Baseline/EL3	94.8	60.1 W T8 & 0.88 BF Elec	174.10	0.00	89.03	0.00	N/A	0.0
	New Lamp & Ballast Purchase	EL4	98.2	60.1 W T8 & 0.85 BF Elec	174.34	-0.24	93.41	1.25	3.5	2.2
		EL5	101.8	57 W T8 & 0.85 BF Elec	165.95	8.15	93.79	2.30	2.1	2.6
		EL5	101.5	60.1 W T8 & 0.78 BF Elec	163.81	10.29	95.12	4.17	1.5	0.1
		EL5	103.6	55 W T8 & 0.88 BF Elec	163.69	10.42	92.98	3.64	1.1	5.6

Table 8.5.16 Summary of the LCC Results for a Two-Lamp 8-Foot Single Pin Slimline System Operating in the Commercial Sector

Baseline	Efficacy Level	LCC Savings 2007\$			Installed Price 2007\$		
		Event IA: Lamp Replacement*	Event II: Standards- Induced Retrofit (Lamp and Ballast Replacement)*	Event III: Ballast Failure*†	Event IA: Lamp Replacement	Event II: Standards- Induced Retrofit (Lamp and Ballast Replacement)	Event III: Ballast Failure†
75 Watt T12	Base-line	N/A	N/A	N/A	16.16	16.16	88.94
	EL1	LL	EN/A	-4.59	LL	EN/A	95.31
	EL2	LL	EN/A	-0.59	LL	EN/A	97.21
	EL3	36.73	EN/A	LL	19.43	EN/A	LL
	EL4	NR	LL	LL	NR	LL	LL
	EL5	NR	11.45	28.45	NR	95.12	92.82
60 Watt T12	Base-line	N/A	N/A	N/A	11.33	11.33	84.11
	EL1	NER	BAE	BAE	BAE	BAE	BAE
	EL2	NER	-24.86	-2.48	16.01	91.10	88.79
	EL3	NER	-24.31 to - 23.98	-1.61	19.43	89.03 to 94.52	92.21
	EL4	NR	-14.90	7.47	NR	93.41	91.10
	EL5	NR	-14.02 to - 12.26	8.35 to 10.12	NR	93.79 to 95.12	91.48 to 92.82
59 Watt T8	Base-line	N/A	EN/A	N/A	12.74	EN/A	86.72
	EL1	BAE	EN/A	BAE	BAE	EN/A	BAE
	EL2	BAE	EN/A	BAE	BAE	EN/A	BAE
	EL3	BAE	EN/A	BAE	BAE	EN/A	BAE
	EL4	NER	EN/A	-0.24	NER	EN/A	91.10
	EL5	6.48 to 10.42	EN/A	8.15 to 10.42	16.68 to 17.50	EN/A	90.67 to 92.82

†For 59-Watt T8 baseline, includes Event V (New Construction and Renovation).

*Analysis period is 4 years.

N/A: Not Applicable; NER: No Energy-Saving Replacement; LL: Available Options Produce Less Light; EN/A: Event Not Applicable; BAE: Baseline Above Efficacy Level; NR: No Replacement

8.5.1.5 Product Class: 8-foot recessed double contact HO $\leq 4,500\text{K}$

For the 8-foot recessed double contact HO $\leq 4,500\text{K}$ product class, DOE analyzed two baseline lamps: a 110W T12 and a 95W T12. Each lamp was analyzed at five efficacy levels.

Table 8.5.17 presents the findings of LCC and PBP analyses on the 8-foot recessed double contact HO GSFL. This table presents the LCC and PBP results for the 8-foot 110W T12 recessed double contact HO baseline lamp operating in the industrial sector. Key inputs consist of using *AEO2008* reference case electricity prices, an analysis period of 2.3 years, and medium-range lamp and ballast prices.

Consumers who own 8-foot 110W T12 recessed double contact HO lamps faced with a lamp failure (Event IA) would be expected to purchase 110W T12 baseline lamps for their magnetic ballast in the base case. The available replacement lamps at EL1 and EL2 do not produce sufficient light output in comparison to the baseline system, so DOE assumes that 8-foot 110W T12 recessed double contact HO consumers would purchase the reduced-wattage (95W) T12 lamp options at EL3 when faced with standard levels EL1 and EL2. Consumers could achieve positive LCC savings with these lamps while incurring installed price increases of \$12.64 or \$13.27.

Standard levels EL4 and EL5 eliminate 8-foot T12 recessed double contact HO lamps from the market, requiring consumers to retrofit their systems to T8 systems in the face of a lamp failure (Event II). The available 8-foot T8 recessed double contact HO system at EL4 does not produce sufficient light in comparison with the baseline system, so DOE assumes that at EL4, consumers would instead purchase the 86W T8 system and 0.88 ballast factor electronic ballast at EL5. Eight-foot 110W T12 recessed double contact HO consumers purchasing this system could achieve positive LCC savings while incurring an installed price increase of \$106.75.

In the face of a ballast failure (Event III), 8-foot 110W T12 recessed double contact HO consumers would be expected to purchase the 110W T12 baseline lamp and a 0.95 ballast factor magnetic ballast in the base case. Consumers who own 8-foot 110W T12 recessed double contact HO systems can purchase replacement systems that comply with EL1, EL3, or EL5 and achieve positive LCC savings. The available systems at EL2 and EL4 do not produce sufficient light, so DOE assumes that in the face of standard levels EL2 or EL4, consumers would purchase systems meeting higher standard levels. At EL1, 8-foot 110W T12 recessed double contact HO consumers could purchase a 110W T12 lamp on an electronic ballast but would achieve the least positive LCC savings. At EL3, consumers could purchase reduced-wattage (95W) lamps on a magnetic ballast or on an electronic ballast. Consumers could achieve the most positive LCC savings of any EL by purchasing the 8-foot 86W T8 recessed double contact HO system available at EL5. Standard levels EL4 and EL5 would eliminate 8-foot T12 recessed double contact HO systems from the market, making the 86W T8 system the only available option.

Event V represents consumers who are renovating an existing building or constructing a new building. Consumers in this scenario can change the spacing of the 8-foot T8 recessed double contact HO system to achieve the same lumens as the baseline T12 system. In this

scenario, the lowest LCC occurs at EL3 with a 8-foot 95W T12 recessed double contact HO lamp and 0.9 BF electronic ballast.

Table 8.5.17 LCC and PBP Results for a Two-Lamp 8-Foot 110W T12 Recessed Double Contact HO System Operating in the Industrial Sector

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Mean Lumens from Baseline %
Event I: Lamp Failure	Baseline	Baseline	80.1	113 W T12 & 0.95 BF Mag	162.72	0.00	19.74	0.00	N/A	0.0
	A: Lamp Replacement	EL3	87.6	97 W T12 & 0.91 BF Mag	155.05	7.67	32.38	10.16	1.2	-10.0
		EL3	88.9	97 W T12 & 0.91 BF Mag	155.68	7.05	33.01	10.16	1.3	-8.9
	B: Lamp & Ballast Replacement	EL1	83.2	113 W T12 & 0.88 BF Elec	182.44	-19.72	113.23	9.45	9.9	-1.6
		EL3	87.6	97 W T12 & 0.91 BF Mag	180.78	-18.05	110.24	10.16	8.9	-10.0
		EL3	88.9	97 W T12 & 0.91 BF Mag	181.40	-18.68	110.86	10.16	9.0	-8.9
		EL3	88.9	97 W T12 & 0.9 BF Elec	172.39	-9.66	114.96	15.34	6.2	-9.9
	EL5	95.3	86 W T8 & 0.88 BF Elec	146.22	16.51	124.19	23.01	4.5	-11.3	
Event II: Standards Induced Retrofit	Baseline	Baseline	80.1	113 W T12 & 0.95 BF Mag	152.11	0.00	19.74	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL1	83.2	113 W T12 & 0.88 BF Elec	183.21	-31.09	115.54	9.45	10.1	-1.6
		EL3	87.6	97 W T12 & 0.91 BF Mag	181.54	-29.43	112.54	10.16	9.1	-10.0
		EL3	88.9	97 W T12 & 0.91 BF Mag	182.17	-30.05	113.17	10.16	9.2	-8.9
		EL3	88.9	97 W T12 & 0.9 BF Elec	173.15	-21.03	117.27	15.34	6.4	-9.9
		EL5	95.3	86 W T8 & 0.88 BF Elec	146.98	5.13	126.49	23.01	4.6	-11.3

Table 8.5.17 LCC and PBP Results for a Two-Lamp 8-Foot 110W T12 Recessed Double Contact HO System Operating in the Industrial Sector (continued)

Event	Response	Efficacy Level	Rated Lamp Efficacy	Design Option	LCC	LCC Savings	Installed Price	Operating Cost Savings (Start Year)	Payback Period	% Mean Lumens from Baseline
			<i>lms/W</i>		\$	\$	\$	\$	<i>yrs</i>	%
Event III: Ballast Failure	Baseline	Baseline	80.1	113 W T12 & 0.95 BF Mag	188.45	0.00	97.60	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL1	83.2	113 W T12 & 0.88 BF Elec	182.44	6.01	113.23	9.45	1.7	-1.6
		EL3	87.6	97 W T12 & 0.91 BF Mag	180.78	7.67	110.24	10.16	1.2	-10.0
		EL3	88.9	97 W T12 & 0.91 BF Mag	181.40	7.05	110.86	10.16	1.3	-8.9
		EL3	88.9	97 W T12 & 0.9 BF Elec	172.39	16.07	114.96	15.34	1.1	-9.9
		EL5	95.3	86 W T8 & 0.88 BF Elec	146.22	42.23	124.19	23.01	1.2	-11.3
Event V: New Construction and Renovation	Baseline	Baseline	80.1	113 W T12 & 0.95 BF Mag	189.22	0.00	99.90	0.00	N/A	0.0
	New Lamp & Ballast Purchase	EL1	83.2	113 W T12 & 0.88 BF Elec	183.21	6.01	115.54	9.45	1.7	-1.6
		EL2	86.1	97 W T12 & 0.9 BF Elec	183.27	5.94	104.32	7.36	5.0	0.0
		EL2	86.1	97 W T12 & 0.91 BF Mag	191.46	-2.25	100.22	2.18	6.2	0.0
		EL3	87.6	97 W T12 & 0.9 BF Elec	193.89	-4.68	116.64	8.48	3.7	0.0
		EL3	87.6	97 W T12 & 0.91 BF Mag	181.54	7.67	112.54	10.16	1.2	-10.0
		EL3	88.9	97 W T12 & 0.9 BF Elec	173.15	16.07	117.27	15.34	1.1	-9.9
		EL3	88.9	97 W T12 & 0.91 BF Mag	182.17	7.05	113.17	10.16	1.3	-8.9
		EL4	91.9	86 W T8 & 0.88 BF Elec	175.58	13.63	123.27	11.61	4.5	0.0
		EL4	93.0	86 W T8 & 0.81 BF Elec	185.17	4.04	123.60	10.95	5.9	0.0
EL5	95.3	86 W T8 & 0.81 BF Elec	173.42	15.79	126.49	15.56	3.5	0.0		

Table 8.5.18 presents the findings of LCC and PBP analyses on 8-foot recessed double contact high-output GSFL. This table presents the LCC and PBP results for the 8-foot 95W T12 recessed double contact HO baseline lamp operating in the industrial sector. Key inputs consist of using *AEO2008* reference case electricity prices, an analysis period of 2.3 years, and medium-range lamp and ballast prices.

When faced with a lamp failure (Event IA), consumers of the 8-foot 95W T12 recessed double contact HO baseline lamp would be expected to purchase the 95W T12 baseline for their magnetic ballast in the base case. This lamp also complies with EL1. None of the lamps available at EL1 through EL3, when in combination with the magnetic ballast save energy as compared to the baseline system. Therefore, results for this event are not shown. However, consumers can purchase these lamps and incur installed price increases ranging from \$6.14 to \$19.09.

Consumers of the 8-foot 95W T12 recessed double contact HO baseline lamp could instead retrofit their systems to save energy (Event II). The EL1 system available for retrofit does not produce sufficient light output, and consumers could not achieve positive LCC savings with any of the system options available for retrofit at EL2 through EL5. Furthermore, standard levels EL4 and EL5 would eliminate 8-foot T12 recessed double contact HO lamps from the market, thereby forcing consumers of the 8-foot 95W T12 recessed double contact HO baseline lamp to retrofit to T8 systems when faced with a lamp failure and incur installed price increases ranging from \$109.35 to \$112.58.

When faced with a ballast failure, consumers of 8-foot 95W T12 recessed double contact HO lamps could purchase a 95W T12 baseline lamp on a magnetic ballast in the base case. Consumers purchasing a higher efficacy 8-foot 95W T12 recessed double contact HO lamp at EL2 on an electronic ballast achieve positive LCC savings. However, consumers purchasing these systems at EL3, would not achieve positive LCC savings. Standard levels EL4 and EL5 would eliminate 8-foot T12 recessed double contact HO systems from the market, making the EL4 and EL5 8-foot 86W recessed double contact HO T8 system the only available option for consumers faced with a ballast failure. Those who purchase the 8-foot 86W T8 recessed double contact HO system at EL4 or EL5 can achieve positive LCC savings.

Event V represents consumers who are renovating an existing building or constructing a new building. Consumers in this scenario can change the spacing of the 8-foot T8 recessed double contact HO system to achieve the same lumens as the baseline T12 system. In this scenario, the lowest LCC occurs at EL4.

Table 8.5.18 LCC and PBP Results for a Two-Lamp 8-Foot 95W T12 Recessed Double Contact HO System Operating in the Industrial Sector

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i>yrs</i>	% Mean Lumens from Baseline %
Event I: Lamp Failure	Baseline	Baseline	82.5	97 W T12 & 0.91 BF Mag	136.59	0.00	13.92	0.00	N/A	0.0
	B: Lamp & Ballast Replacement	EL2	86.1	97 W T12 & 0.89 BF Elec	156.85	-20.26	102.01	6.48	13.6	5.8
		EL3	87.6	97 W T12 & 0.88 BF Elec	166.58	-29.99	114.33	7.78	12.9	6.4
		EL3	88.9	97 W T12 & 0.88 BF Elec	167.21	-30.62	114.96	7.78	13.0	7.8
		EL4	91.9	86 W T8 & 0.88 BF Elec	141.02	-4.43	120.96	12.85	8.3	-1.2
		EL4	93.0	86 W T8 & 0.88 BF Elec	144.18	-7.59	121.29	12.85	8.4	0.2
		EL5	95.3	86 W T8 & 0.81 BF Elec	140.84	-4.25	124.19	15.54	7.1	-0.1
Event II: Standards Induced Retrofit	Baseline	Baseline	82.5	97 W T12 & 0.91 BF Mag	128.90	0.00	13.92	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL2	86.1	97 W T12 & 0.89 BF Elec	157.61	-28.71	104.32	6.48	13.9	5.8
		EL3	87.6	97 W T12 & 0.88 BF Elec	167.35	-38.44	116.64	7.78	13.2	6.4
		EL3	88.9	97 W T12 & 0.88 BF Elec	167.97	-39.07	117.27	7.78	13.3	7.8
		EL4	91.9	86 W T8 & 0.88 BF Elec	141.78	-12.88	123.27	12.85	8.5	-1.2
		EL4	93.0	86 W T8 & 0.88 BF Elec	144.94	-16.04	123.60	12.85	8.5	0.2
		EL5	95.3	86 W T8 & 0.81 BF Elec	141.60	-12.70	126.49	15.54	7.2	-0.1

Table 8.5.18 LCC and PBP Results for a Two-Lamp 8-Foot 95W T12 Recessed Double Contact HO System Operating in the Industrial Sector (continued)

Event	Response	Efficacy Level	Rated Lamp Efficacy <i>lms/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period <i> yrs</i>	% Mean Lumens from Baseline %
Event III: Ballast Failure	Baseline	Baseline	82.5	97 W T12 & 0.91 BF Mag	162.32	0.00	91.77	0.00	N/A	0.0
	Lamp & Ballast Replacement	EL2	86.1	97 W T12 & 0.89 BF Elec	156.85	5.47	102.01	6.48	1.6	5.8
		EL3	87.6	97 W T12 & 0.88 BF Elec	166.58	-4.27	114.33	7.78	2.9	6.4
		EL3	88.9	97 W T12 & 0.88 BF Elec	167.21	-4.89	114.96	7.78	3.0	7.8
		EL4	91.9	86 W T8 & 0.88 BF Elec	141.02	21.30	120.96	12.85	2.3	-1.2
		EL4	93.0	86 W T8 & 0.88 BF Elec	144.18	18.13	121.29	12.85	2.3	0.2
EL5	95.3	86 W T8 & 0.81 BF Elec	140.84	21.47	124.19	15.54	2.1	-0.1		
Event V: New Construction and Renovation	Baseline	Baseline	82.5	97 W T12 & 0.91 BF Mag	163.08	0.00	94.08	0.00	N/A	0.0
	New Lamp & Ballast Purchase	EL2	86.1	97 W T12 & 0.89 BF Elec	157.61	5.47	104.32	6.48	1.6	5.8
		EL3	87.6	97 W T12 & 0.88 BF Elec	167.35	-4.27	116.64	7.78	2.9	6.4
		EL3	88.9	97 W T12 & 0.88 BF Elec	167.97	-4.89	117.27	7.78	3.0	7.8
		EL4	91.9	86 W T8 & 0.88 BF Elec	141.78	21.30	123.27	12.85	2.3	-1.2
		EL4	93.0	86 W T8 & 0.88 BF Elec	144.94	18.13	123.60	12.85	2.3	0.2
EL5	95.3	86 W T8 & 0.81 BF Elec	141.60	21.47	126.49	15.54	2.1	-0.1		

Table 8.5.19 summarizes the range of results for the 8-foot recessed double contact HO product class. Only the most relevant events under each baseline lamp are shown. An EL at or above EL3 would induce the replacement of T12 electronic ballasts with electronic T8 ballasts, as no 8-foot 95W or 110W recessed double contact HO T12 lamps meet these ELs. This migration may result in negative LCC savings for consumers who would not otherwise replace their T12 electronic system.

Table 8.5.19 Summary of the LCC Results for a Two-Lamp 8-Foot Recessed Double-Contact HO System Operating in the Industrial Sector

Baseline	Efficacy Level	LCC Savings 2007\$			Installed Price 2007\$		
		Event IA: Lamp Replacement *	Event II: Standards- Induced Retrofit (Lamp and Ballast Replacement) *	Event III: Ballast Failure*	Event IA: Lamp Replacement	Event II: Standards- Induced Retrofit (Lamp and Ballast Replacement)	Event III: Ballast Failure
110 Watt T12	Base-line	N/A	N/A	N/A	19.74	19.74	97.60
	EL1	LL	EN/A	6.01	LL	EN/A	113.23
	EL2	LL	EN/A	LL	LL	EN/A	LL
	EL3	7.05 to 7.67	EN/A	7.05 to 16.07	32.38 to 33.01	EN/A	110.24 to 114.96
	EL4	NR	LL	LL	NR	LL	LL
EL5	NR	5.13	42.23	NR	126.49	124.19	
95 Watt T12	Base-line	N/A	N/A	N/A	13.92	13.92	91.77
	EL1	NER	LL	LL	BAE	LL	LL
	EL2	NER	-28.71	5.47	20.06	104.32	102.01
	EL3	NER	-39.07 to - 38.44	-4.89 to -4.27	32.38 to 33.01	116.64 to 117.27	114.33 to 114.96
	EL4	NR	-16.04 to - 12.88	18.13 to 21.30	NR	123.27 to 123.60	120.96 to 121.29
	EL5	NR	-12.70	21.47	NR	126.49	124.19

*Analysis period is 2.3 years.

N/A: Not Applicable; NER: No Energy-Saving Replacement; LL: Available Options Produce Less Light;
EN/A: Event Not Applicable; NR: No Replacement

8.5.2 Life-Cycle Cost Results for Incandescent Reflector Lamps

The following tables present the findings of the LCC and PBP analyses on standard-spectrum IRL. Table 8.5.20 provides the LCC and PBP results for a 90W PAR38 lamp operating in the commercial sector. These results are based on the *AEO2008* reference case electricity prices, an analysis period of 0.9 years in the commercial sector and 3.4 years in the residential sector, and medium-range lamp prices.

Table 8.5.20, Table 8.5.22, and Table 8.5.24 provide the LCC and PBP results for a 90W PAR38, 75W PAR38, and 50W PAR30 lamp operating in the commercial sector. These results are based on the *AEO2008* reference case electricity prices, an analysis period of 0.9 years, and medium-range lamp prices.

Table 8.5.21, Table 8.5.23, Table 8.5.25 provides the LCC and PBP results for a 90W PAR38, 75W PAR38, and 50W PAR30 lamp operating in the residential sector. These results are based on the *AEO2008* reference case electricity prices, an analysis period of 3.4 years, and medium-range lamp prices.

In general, the majority of efficacy levels result in positive LCC savings in spite of the higher installed prices of the standards-case lamps in comparison with the baseline lamps. At EL1, in all but the residential 90W PAR38 baseline, consumers would achieve negative LCC savings when purchasing the improved halogen (xenon) lamp. The improved halogen (xenon) lamp at this efficacy level would not save enough energy to recover its increased initial cost from the baseline lamp. Maximum LCC savings would be achieved at EL5 for the 90W and 75W baselines when a consumer purchases an improved halogen infrared (HIR) plus lamp. For the 50W baseline, both the EL4 and EL5 replacement lamps are 40W, as this is the lowest-wattage IRL covered by standards. Therefore, EL4, consuming the same amount of energy and with a lower lamp price, would have higher LCC savings than EL5. In general, the lamps with the highest LCC savings are more efficacious and have longer lifetimes than the baseline lamps.

Table 8.5.20 LCC and PBP Results for a 90W PAR38 Lamp Operating in the Commercial Sector

Event	Response	Efficacy Level	Lamp Efficacy lms/W	Lamp Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Initial Lumens from Baseline %
Event I: Lamp Failure; or Event V: New Construction and Renovation	Baseline	Baseline	14.6	90W, 14.6lm/W & 2500hrs, Halogen	33.90	0.00	6.20	0.00	N/A	0.0
	Lamp Replacement or New Lamp Purchase	EL1	15.3	85.7W, 15.3lm/W & 2500hrs, Improved Halogen (Xenon)	33.93	-0.03	7.14	1.31	0.7	0.0
		EL2	15.9	82.5W, 15.9lm/W & 6000hrs, Long Life HIR	27.86	6.04	7.76	2.29	0.7	0.0
		EL2	16.6	79W, 16.6lm/W & 3000hrs, Improved Halogen (Silver)	30.10	3.81	7.58	3.35	0.4	0.0
		EL3	18.0	70W, 18lm/W & 3000hrs, HIR	27.71	6.19	7.76	6.10	0.3	-3.8
		EL4	19.8	66W, 19.8lm/W & 4000hrs, Improved HIR	25.77	8.14	9.08	7.32	0.4	0.0
		EL5	21.0	60W, 21lm/W & 4200hrs, Improved HIR Plus	24.49	9.41	9.65	9.15	0.4	-3.8

Table 8.5.21 LCC and PBP Results for a 90W PAR38 Lamp Operating in the Residential Sector

Event	Response	Efficacy Level	Lamp Efficacy lms/W	Lamp Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Initial Lumens from Baseline %
Event I: Lamp Failure; or Event V: New Construction and Renovation	Baseline	Baseline	14.6	90W, 14.6lm/W & 2500hrs, Halogen	33.04	0.00	5.13	0.00	N/A	0.0
	Lamp Replacement or New Lamp Purchase	EL1	15.3	85.7W, 15.3lm/W & 2500hrs, Improved Halogen (Xenon)	32.92	0.12	6.07	0.43	2.2	0.0
		EL2	15.9	82.5W, 15.9lm/W & 6000hrs, Long Life HIR	28.36	4.68	6.70	0.74	2.1	0.0
		EL2	16.6	79W, 16.6lm/W & 3000hrs, Improved Halogen (Silver)	29.98	3.06	6.52	1.09	1.3	0.0
		EL3	18.0	70W, 18lm/W & 3000hrs, HIR	27.49	5.55	6.70	1.98	0.8	-3.8
		EL4	19.8	66W, 19.8lm/W & 4000hrs, Improved HIR	25.95	7.09	8.02	2.38	1.2	0.0
		EL5	21.0	60W, 21lm/W & 4200hrs, Improved HIR Plus	24.28	8.76	8.59	2.98	1.2	-3.8

Table 8.5.22 LCC and PBP Results for a 75W PAR38 Lamp Operating in the Commercial Sector

Event	Response	Efficacy Level	Lamp Efficacy lms/W	Lamp Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Initial Lumens from Baseline %
Event I: Lamp Failure; or Event V: New Construction and Renovation	Baseline	Baseline	14.0	75W, 14lm/W & 2500hrs, Halogen	29.63	0.00	6.20	0.00	N/A	0.0
	Lamp Replacement or New Lamp Purchase	EL1	14.6	71.7W, 14.6lm/W & 2500hrs, Improved Halogen (Xenon)	29.94	-0.31	7.14	1.01	0.9	0.0
		EL2	15.3	68.8W, 15.3lm/W & 6000hrs, Long Life HIR	23.96	5.67	7.76	1.89	0.8	0.0
		EL2	15.9	66W, 15.9lm/W & 3000hrs, Improved Halogen (Silver)	26.39	3.24	7.58	2.74	0.5	0.0
		EL3	17.5	60W, 17.5lm/W & 3000hrs, HIR	24.86	4.77	7.76	4.57	0.3	0.0
		EL4	19.1	55W, 19.1lm/W & 4000hrs, Improved HIR	22.63	7.00	9.08	6.10	0.5	0.0
		EL5	20.3	51.7W, 20.3lm/W & 4200hrs, Improved HIR Plus	22.13	7.50	9.65	7.11	0.5	0.0

Table 8.5.23 LCC and PBP Results for a 75W PAR38 Lamp Operating in the Residential Sector

Event	Response	Efficacy Level	Lamp Efficacy lms/W	Lamp Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Initial Lumens from Baseline %
Event I: Lamp Failure; or Event V: New Construction and Renovation	Baseline	Baseline	14.0	75W, 14lm/W & 2500hrs, Halogen	28.58	0.00	5.13	0.00	N/A	0.0
	Lamp Replacement or New Lamp Purchase	EL1	14.6	71.7W, 14.6lm/W & 2500hrs, Improved Halogen (Xenon)	28.76	-0.18	6.07	0.33	2.9	0.0
		EL2	15.3	68.8W, 15.3lm/W & 6000hrs, Long Life HIR	24.29	4.30	6.70	0.61	2.5	0.0
		EL2	15.9	66W, 15.9lm/W & 3000hrs, Improved Halogen (Silver)	26.12	2.46	6.52	0.89	1.6	0.0
		EL3	17.5	60W, 17.5lm/W & 3000hrs, HIR	24.52	4.07	6.70	1.49	1.1	0.0
		EL4	19.1	55W, 19.1lm/W & 4000hrs, Improved HIR	22.69	5.90	8.02	1.98	1.5	0.0
		EL5	20.3	51.7W, 20.3lm/W & 4200hrs, Improved HIR Plus	21.81	6.77	8.59	2.31	1.5	0.0

Table 8.5.24 LCC and PBP Results for a 50W PAR30 Lamp Operating in the Commercial Sector

Event	Response	Efficacy Level	Lamp Efficacy lms/W	Lamp Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Initial Lumens from Baseline %
Event I: Lamp Failure; or Event V: New Construction and Renovation	Baseline	Baseline	12.6	50W, 12.6lm/W & 3000hrs, Halogen	19.84	0.00	5.59	0.00	N/A	0.0
	Lamp Replacement or New Lamp Purchase	EL1	13.2	47.8W, 13.2lm/W & 3000hrs, Improved Halogen (Xenon)	20.15	-0.31	6.53	0.67	1.4	0.0
		EL2	13.5	46W, 13.5lm/W & 6000hrs, Long Life HIR	17.12	2.72	7.15	1.22	1.3	-1.6
		EL2	14.0	45W, 14lm/W & 3000hrs, Improved Halogen (Silver)	19.80	0.04	6.98	1.52	0.9	0.0
		EL3	15.1	41.8W, 15.1lm/W & 3000hrs, HIR	19.07	0.77	7.15	2.50	0.6	0.0
		EL4	17.0	40W, 17lm/W & 4000hrs, Improved HIR	17.89	1.95	8.47	3.05	0.9	7.9
		EL5	19.1	40W, 19.1lm/W & 4200hrs, Improved HIR Plus	18.33	1.51	9.04	3.05	1.1	21.4

Table 8.5.25 LCC and PBP Results for a 50W PAR30 Lamp Operating in the Residential Sector

Event	Response	Efficacy Level	Lamp Efficacy lms/W	Lamp Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings (Start Year) \$	Payback Period yrs	% Initial Lumens from Baseline %
Event I: Lamp Failure; or Event V: New Construction and Renovation	Baseline	Baseline	12.6	50W, 12.6lm/W & 3000hrs, Halogen	19.38	0.00	4.53	0.00	N/A	0.0
	Lamp Replacement or New Lamp Purchase	EL1	13.2	47.8W, 13.2lm/W & 3000hrs, Improved Halogen (Xenon)	19.66	-0.28	5.46	0.22	4.3	0.0
		EL2	13.5	46W, 13.5lm/W & 6000hrs, Long Life HIR	17.17	2.21	6.09	0.40	3.9	-1.6
		EL2	14.0	45W, 14lm/W & 3000hrs, Improved Halogen (Silver)	19.28	0.10	5.92	0.50	2.8	0.0
		EL3	15.1	41.8W, 15.1lm/W & 3000hrs, HIR	18.51	0.87	6.09	0.81	1.9	0.0
		EL4	17.0	40W, 17lm/W & 4000hrs, Improved HIR	17.75	1.62	7.41	0.99	2.9	7.9
		EL5	19.1	40W, 19.1lm/W & 4200hrs, Improved HIR Plus	17.88	1.49	7.98	0.99	3.5	21.4

8.6 DETAILED RESULTS AND SENSITIVITY RUNS

DOE presents more detailed results and sensitivity runs from the LCC analysis in Appendix 8B. These results include Monte Carlo probability distributions, price sensitivity scenarios, and operating hour sensitivity scenarios.

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