CHAPTER 4. LIFE-CYCLE COSTS AND PAYBACK PERIODS

Ballasts that are more energy efficient than those required by the existing ballast standard would likely be more expensive to purchase but less expensive to operate. The net effect of these cost changes on commercial and industrial customers is analyzed by calculating life-cycle cost (LCC), using the equipment prices and engineering data from Chapter 3, together with an assumed electricity price. Section 4.1 presents the LCC results for each energy-efficient ballast technology option, and Section 4.2 discusses the payback periods for these design options.

The impact of changing energy-efficiency levels is expressed by two measures:

- Section 4.1: Change in Life-Cycle Cost (LCC) resulting from the purchase and use of an energy-efficient ballast,

- Section 4.2: Payback Period (PAY) for the more energy-efficient ballast.

Section 4.3 presents the results of sensitivity analyses using high and low consumer discount rates different projections of future energy prices..

4.1 LIFE-CYCLE COST FOR TECHNOLOGY OPTIONS

LCC is the sum of purchase price (*PC*) and operating expense (*OC*) discounted at rate *r* over the lifetime (*N*) of the appliance. Installation costs, such as equipment and labor, are included in PC,

$$LCC = PC + \sum_{t=1}^{N} \frac{OC_t}{(1+r)^t} \tag{4.1}$$

and energy consumption and lamp replacements (and associated labor) during the life of a ballast are included in OC. Discounting means that money spent (or saved) at some future date has less value than the same expenditures (or savings) in the immediate present.

If operating expenses are constant over time, Eq. 4.1 simplifies to:

$$LCC = PC + PWF \cdot OC, \tag{4.2}$$

where the present worth factor (PWF) is:

$$PWF = \sum_{t=1}^{N} \frac{1}{(1+r)^t} = \frac{1}{r}\left[1 - \frac{1}{(1+r)^N}\right] \tag{4.3}$$

The LCC is calculated for each lamp/ballast combination.

4.1.1 LCC Data Inputs

Data inputs to LCC calculations include end-user prices for ballasts and lamps, electricity rates ($/kWh), annual lighting operating hours, labor rates, installation times, analysis period, ballast lifetimes, lamp lifetimes, and discount rates.

Ballast Price Distribution. Chapter 3 describes the methodology used to determine the end-user prices for ballasts. The LCC analysis uses incremental price for converting from the baseline EEM T12 ballast to a more efficient design option. These incremental prices are listed in Table 4.1 below. A normal distribution with the mean equal to the incremental price and a standard deviation of 15% was used to describe the distribution of incremental ballast prices.

Table 4.1 Average and Standard Deviation of Incremental Ballast Prices

	Incremental Ballast Price Distribution (1997$)					
Product Class	**Mean Value**			**Standard Deviation**		
	CC	**T12 ERS**	**T8 ERS**	**CC**	**T12 ERS**	**T8 ERS**
1-Lamp Fixture	6.84	12.86	6.69	1.03	1.93	1.00
2-Lamp Fixture	9.04	11.40	8.37	1.36	1.71	1.26
3-Lamp Fixture (tw)	13.56	17.10	12.55	2.03	2.57	1.88
3-Lamp Fixture (non tw)	15.88	10.47	-4.03	2.38	1.57	0.60
4-Lamp Fixture	18.08	17.03	-1.45	2.71	2.55	0.22
2F96/ES	NA	17.37		NA	2.61	
2F96HO/ES	3.57	12.05		0.54	1.81	

Electricity Price Distribution. Marginal electricity prices in $1997/kWh are used. A detailed explanation of the process for deriving these marginal electricity rates can be found in Appendix B. Electricity prices projected for the year 2003 are used because that is the earliest year in which changes to the minimum ballast efficiency standards could occur. Each ballast type is assumed to be used primarily in either the commercial or industrial sector, and the appropriate electricity rate for that sector is used to calculate the LCC. Ballasts driving F40T12/ES and F32T8 lamps are assumed to operate primarily in the commercial sector. We estimate that about 75% of 2F96T12 and 65% of 2F06T12HO lamps, respectively, are operated in the commercial sector (see Appendix A). Sensitivities are also done for 2F96T12 lamps and for 2F96T12HO lamps in the industrial sector.

Electricity price is a function of the average price distribution obtained from the Energy Information Agency's data on revenue and sales, for the industrial and commercial sectors by utility, and the epsilons discussed in Appendix B. Epsilon is the percent difference between the average electricity price and the marginal price calculated for each customer on each tariff (the average epsilon is 5.5%). Figures 4.1 and 4.2 present the distribution of sales-weighted average electricity rates in the commercial (\$0.0762/kWh weighted average) and industrial sectors (\$0.0455/kWh weighted average), and figure 4.3 presents the epsilon distribution. For each selected point on the average rate distribution, the software program Crystal Ball, selects an epsilon value. Thus, a marginal rate is calculated by the following equation:

Marginal Electricity Rate = Sales Weighted Average Rate x (1 + Epsilon)

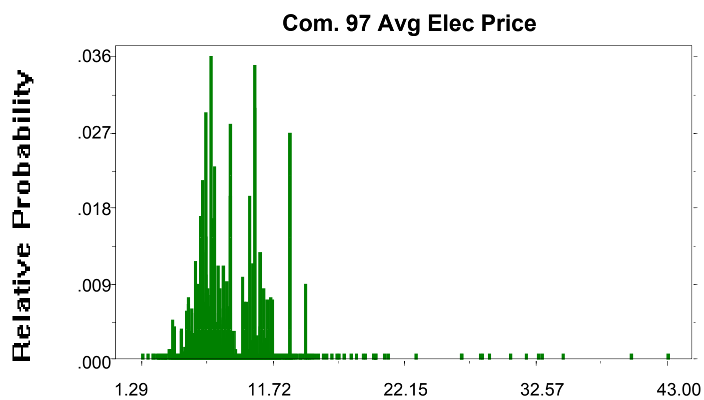

Figure 4.1 Distribution of 1997 Average Commercial Electricity Prices

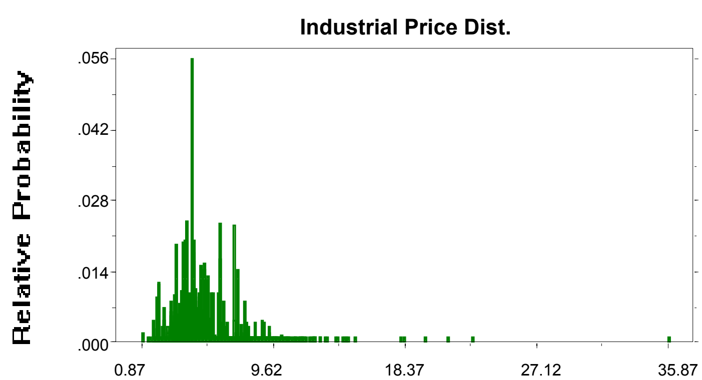

Figure 4.2 Distribution of 1997 Average Industrial Electricity Prices

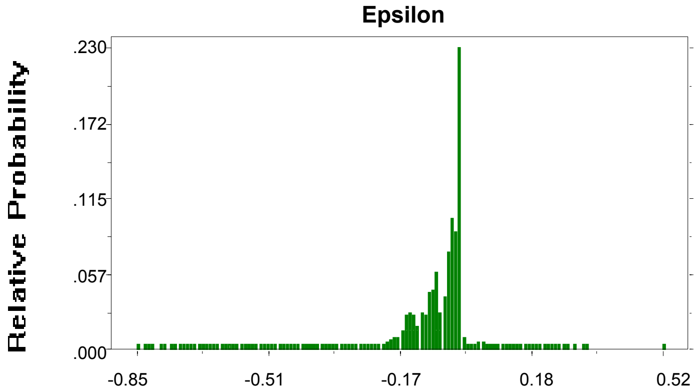

Figure 4.3 Distribution of Epsilons

Energy Price Forecast. Table 4.2 below shows the AEO 1999 forecast for the price of electricity relative to the 1997 baseline. Using the Reference case, these ratios were used to estimate the future marginal prices. Electricity prices are assumed to remain constant after 2020.

Table 4.2 AEO 1999 Average Electricity Price Forecast

	Commercial Electricity Price			Industrial Electricity Price		
Year	**Reference**	**High**	**Low**	**Reference**	**High**	**Low**
1997	1.00	1.00	1.00	1.00	1.00	1.00
1998	0.98	0.98	0.98	0.97	0.97	0.97
1999	0.96	0.97	0.95	0.97	0.98	0.97
2000	0.94	0.95	0.93	0.96	0.97	0.95
2001	0.93	0.94	0.91	0.95	0.96	0.93
2002	0.91	0.92	0.88	0.94	0.96	0.92
2003	0.91	0.93	0.87	0.95	0.97	0.92
2004	0.91	0.94	0.87	0.94	0.97	0.91
2005	0.90	0.94	0.86	0.93	0.96	0.89
2006	0.90	0.94	0.85	0.91	0.95	0.87
2007	0.89	0.93	0.83	0.90	0.94	0.85
2008	0.88	0.92	0.82	0.89	0.93	0.83
2009	0.87	0.92	0.81	0.88	0.92	0.83
2010	0.86	0.92	0.80	0.88	0.92	0.82
2011	0.85	0.91	0.78	0.86	0.91	0.80
2012	0.84	0.90	0.76	0.84	0.90	0.78
2013	0.83	0.89	0.75	0.83	0.89	0.77
2014	0.82	0.89	0.75	0.83	0.89	0.76
2015	0.82	0.89	0.74	0.82	0.88	0.75
2016	0.81	0.88	0.73	0.81	0.87	0.74
2017	0.81	0.88	0.72	0.81	0.87	0.73
2018	0.81	0.88	0.71	0.80	0.87	0.72
2019	0.80	0.88	0.70	0.79	0.86	0.71
2020	0.79	0.87	0.69	0.79	0.86	0.70

Annual Lighting Operating Hours. Annual lighting hours were derived from a large data set of lighting energy audits done throughout the U.S. Annual interior lighting hours were calculated for various commercial-sector building types: office, retail, grocery, restaurant, lodging, health, assembly, school, college, and warehouse. Interior lighting hours were also calculated for industrial buildings. Appendix A describes the derivation of the weighted averages for each lamp type. Figures 4.4 through Figure 4.9 show the annual operating hours distributions for various lamp types. The average lighting hours are found in chapter 3.

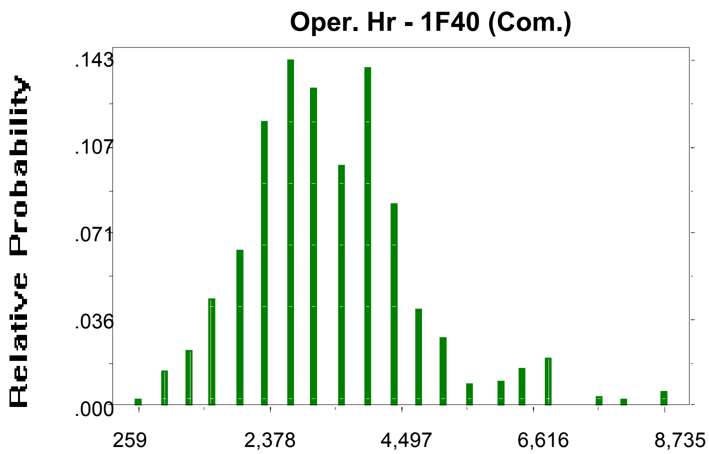

Figure 4.4 Annual Lighting Operation Hours Distribution for 1F40T12 in Commercial Sector

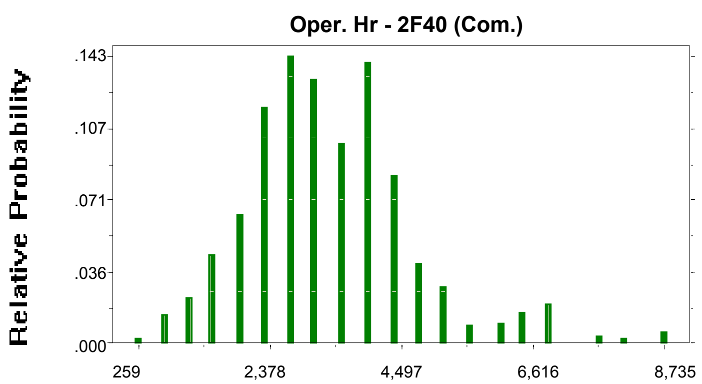

Figure 4.5 Annual Lighting Operation Hours Distribution for 2F40T12 in Commercial Sector

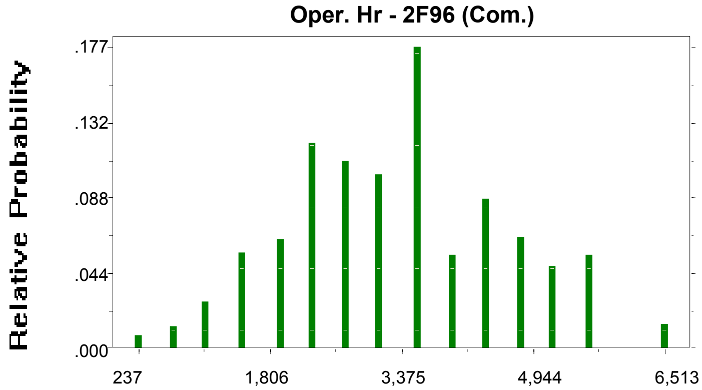

Figure 4.6 Annual Lighting Operation Hours Distribution for 2F96T12 in Commercial Sector

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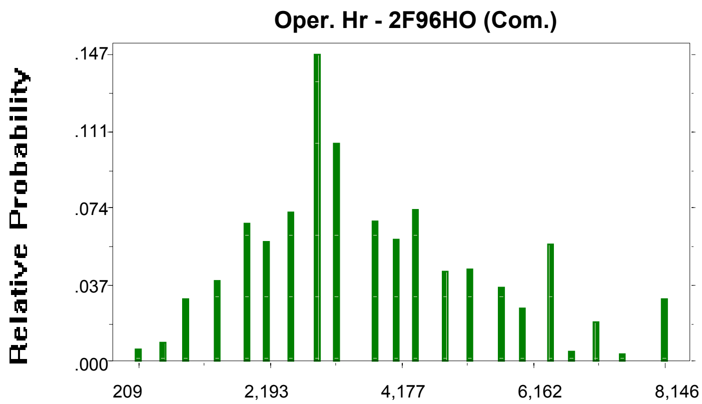

Figure 4.7 Annual Lighting Operation Hours Distribution for 2F96T12HO in Commercial Sector

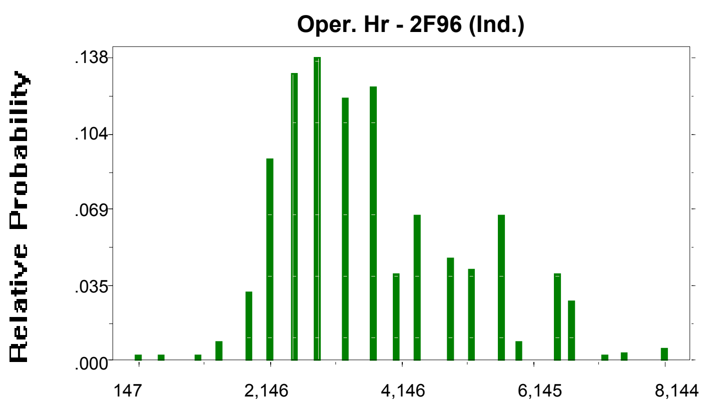

Figure 4.8 Annual Lighting Operation Hours Distribution for 2F96T12 in Industrial Sector

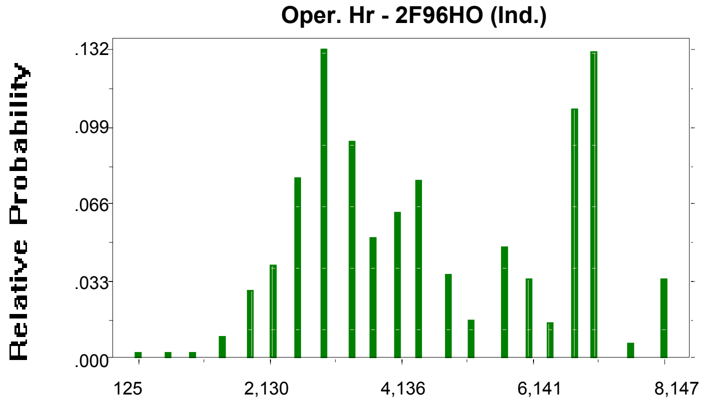

Figure 4.9 Annual Lighting Operation Hours Distribution for 2F96T12HO in Industrial Sector

Ballast Life. The period for this analysis is the ballast service life, which is the ballast rated lifetime divided by the annual lighting hours. The value of 50,000 hours for both magnetic and electronic ballasts has been agreed to by most stakeholders and also used in the previous analysis. For a four-foot lamp with a life of 50,000 hours, operated 3,400 hours/year, the period of analysis would be 50,000 hours/ 3,600 hours/year = 14.7 years. The period of analysis therefore varies according the life of each ballast and its annual operating hours. Figure 4.10 shows the ballast life distribution assumed for this analysis. This is a Weibull distribution starting at 18,000 hour life. Weibull distributions describe data resulting from life and fatigue tests and are commonly used to describe failure time in reliability studies.

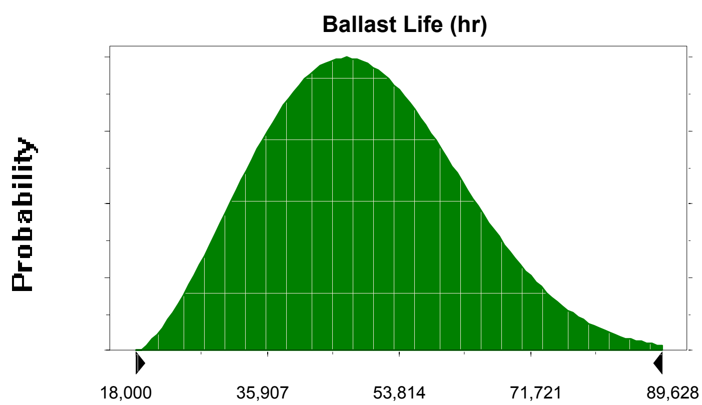

Figure 4.10 Ballast Life Distribution in hours

Installation Costs. A detailed discussion of installation costs and lamp prices can be found in Appendix A.

Discount Rates. A discount rate of 8% real was chosen by the U.S. Department of Energy (DOE).

4.1.2 LCC Results

In this section, we describe probability-based life-cycle cost analyses performed to account for the full range of possible values for four of the most important LCC input variables: ballast life, ballast price, ballast operating hours, and electricity rate. LCC changes and payback periods are calculated using a probability distribution of possible values for the input variables weighted by their likelihood of occurrence and Monte Carlo simulation. The model used to calculate the LCC and payback periods can be found at the DOE Office of Codes and Standards website (URL: http://www.eren.doe.gov/buildings/codes_standards/applbrf/ballast.html). A description of the LCC model can also be found in Section A.7 of Appendix A of this document. The probability distributions for the key variables are shown in figures 4.1 to 4.10. Figures 4.11 to 4.32 present the changes in life-cycle cost as a result of switching from the baseline energy-efficient T12 magnetic ballast to one of the higher-efficiency product types. Figures 4.33 to 4.38 present the same changes for 1 and 2 lamp T8 Ballasts, but use an energy efficient T8 magnetic ballast as the baseline. In particular, the figures show the probability that a particular delta life-cycle cost will occur. This can be interpreted as the fraction of the ballast population that experiences a particular delta LCC.

Energy Efficient T12 Magnetic Ballast Baseline. Table 4.3 summarizes the life-cycle cost savings (delta LCC) for each lamp/ballast combination. Delta LCC is the change in LCC when converting from the baseline option of an EEM ballast to the listed design option. Positive values mean there is a reduction in LCC. The column labeled **% of Baseline LCC** is the mean delta LCC divided by the baseline LCC (expressed as a percentage) obtained when average point values of the inputs are used. It can be seen, that in many cases the mean delta LCC is a small percentage of the total LCC. Changes in LCC of a few percent in either direction can be considered (within the uncertainty of the calculations) as negligible. The column titled **% Reduced LCC** represents the probability of the design option resulting in reduced LCC. A positive number means that the LCC decreased relative to the baseline.

For ballasts operating three or four lamps, we have analyzed two wiring alternatives. For the three lamp case, we analyzed a tandem-wired case where 2-lamp ballasts only are utilized and a case where a one-lamp and a two-lamp ballast are used together to operate three lamps. Dual switching is possible in either case assuming the area is wired appropriately. For the four lamp case, we analyzed a single 4-lamp T8 ballast operating all four lamps under two situations. One case is with ordinary wiring and the second case is with tandem-wiring added, which allows for dual switching. For the latter case, we have estimated an additional cost of $10 for materials and labor.

Table 4.3 Summary of Delta LCC* Results Using an T12 EEM Ballast as the Baseline

Product Class	**Design Option**	**Sector**	**Delta LCC**		
			Mean (1997$)	**% of Baseline LCC**	**% Reduced** ** LCC
1F40					
	T12 CC	Commercial	-4	-3%	7%
	T12 ERS	Commercial	4	3%	68%
	T8 ERS	Commercial	17	13%	98%
2F40					
	T12 CC	Commercial	-2	-1%	31%
	T12 ERS	Commercial	6	3%	80%
	T8 ERS	Commercial	18	9%	98%
3F40					
Tandem-Wired	T12 CC	Commercial	-2	-1%	33%
	T12 ERS	Commercial	5	2%	68%
	T8 ERS	Commercial	27	10%	98%
Not Tandem-Wired	T12 CC	Commercial	-4	-1%	23%
	T12 ERS	Commercial	18	6%	98%
	T8 ERS	Commercial	56	20%	100%
4F40					
	T12 CC	Commercial	-2	-1%	36%
	T12 ERS	Commercial	12	4%	87%
Tandem-Wired***	T8 ERS	Commercial	44	13%	99%
Not Tandem-Wired	T8 ERS	Commercial	54	16%	100%
2F96					
	T12 EIS	Commercial	7	2%	75%
	T12 EIS	Industrial	-2	-1%	35%
2F96HO					
	T12 CC	Commercial	11	2%	90%
	T12 ERS	Commercial	28	5%	98%
	T12 CC	Industrial	1	0%	50%
	T12 ERS	Industrial	15	4%	94%

* A positive Delta LCC implies a LCC savings whereas a negative number implies an increase in LCC.
** % ballasts with reduced life cycle cost.
*** 4F32T8 ERS ballast with Dual Switching includes a $10 incremental increase in labor and materials.

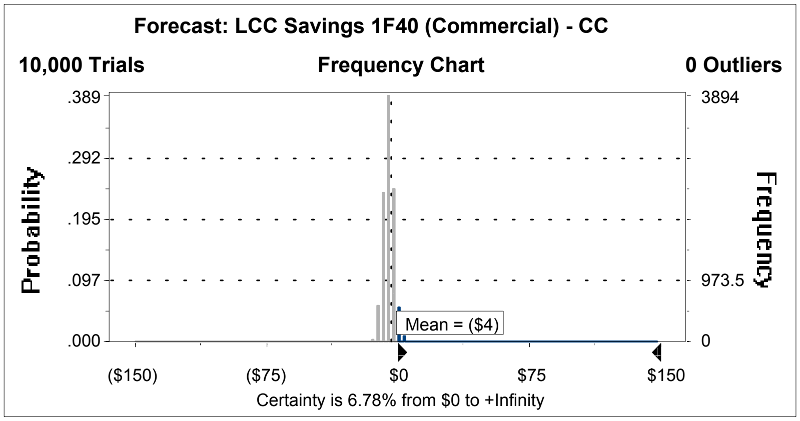

Figure 4.11 Life-Cycle Cost Savings for 1F40T12 CC in Commercial Sector

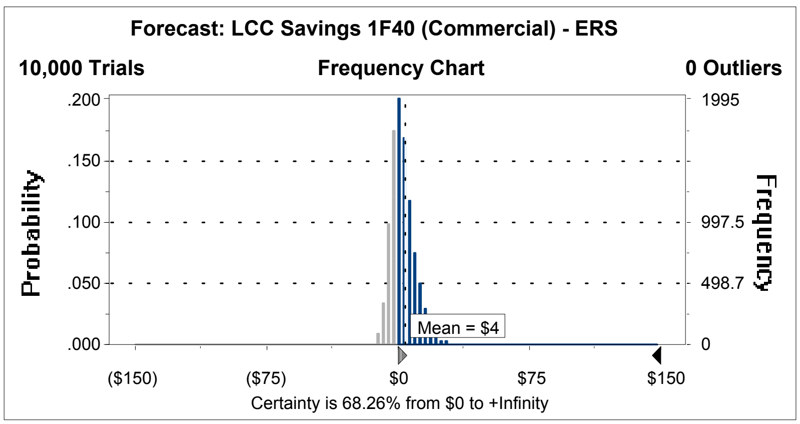

Figure 4.12 Life-Cycle Cost Savings for 1F40T12 ERS in Commercial Sector

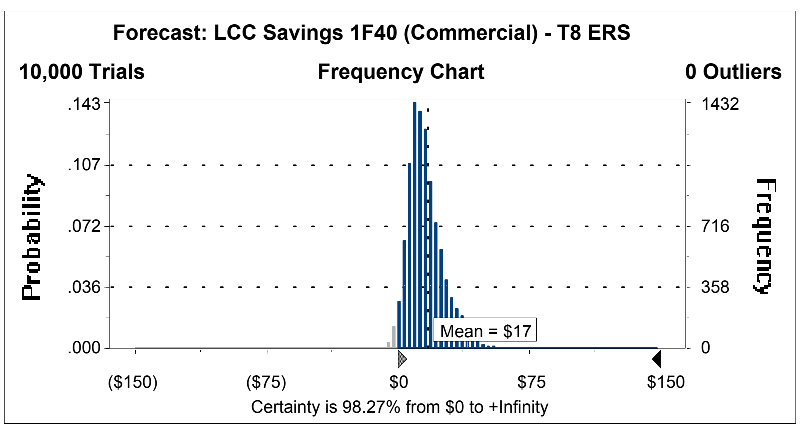

Figure 4.13 Life-Cycle Cost Savings for 1F32T8 ERS in Commercial Sector

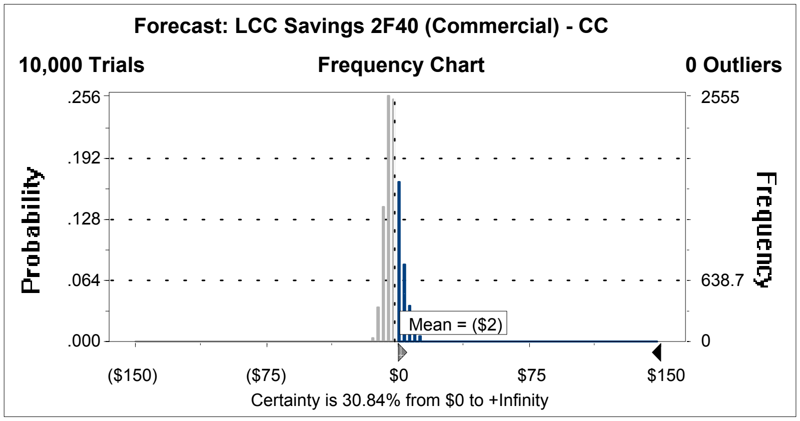

Figure 4.14 Life-Cycle Cost Savings for 2F40T12 CC in Commercial Sector

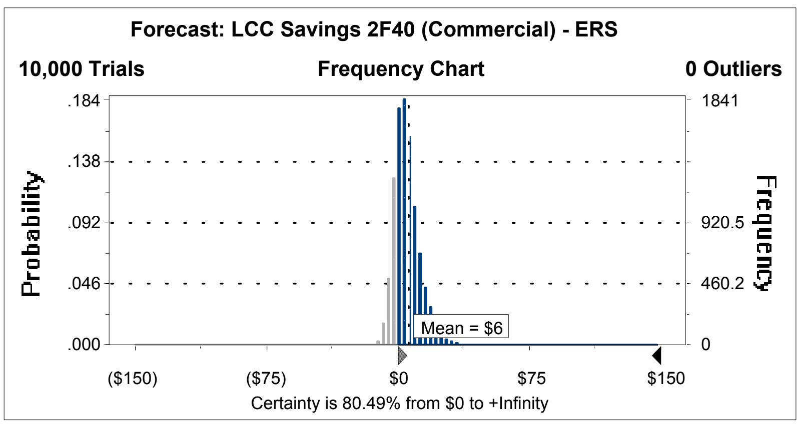

Figure 4.15 Life-Cycle Cost Savings for 2F40T12 ERS in Commercial Sector

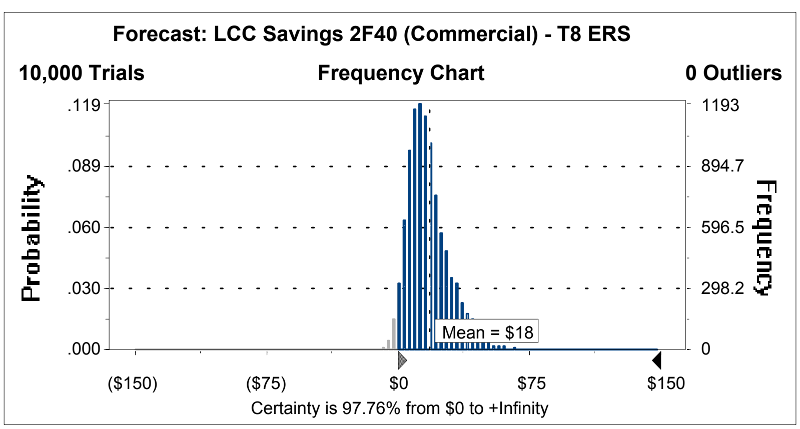

Figure 4.16 Life-Cycle Cost Savings for 2F32T8 ERS in Commercial Sector

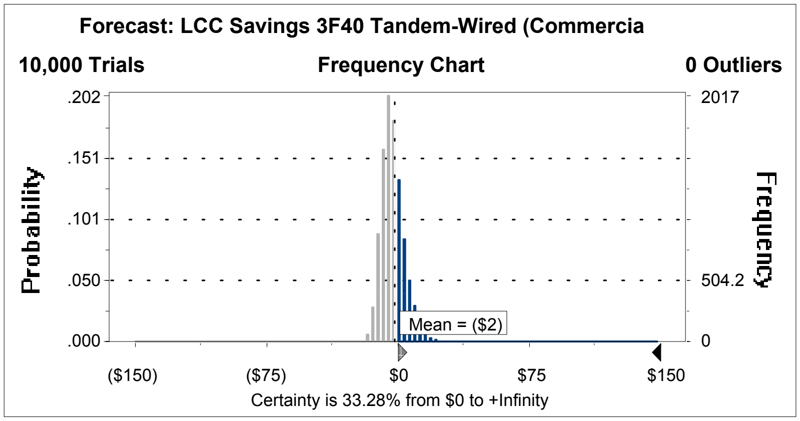

Figure 4.17 Life-Cycle Cost Savings for Tandem-Wired 3F40T12 CC in Commercial Sector

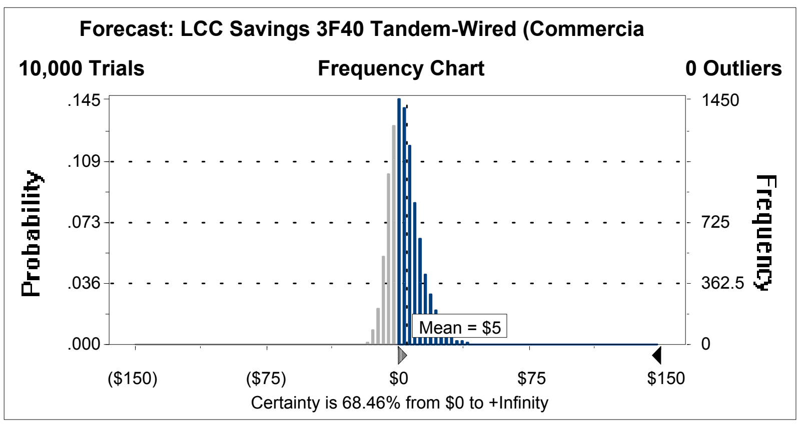

Figure 4.18 Life-Cycle Cost Savings for Tandem-Wired 3F40T12 ERS in Commercial Sector

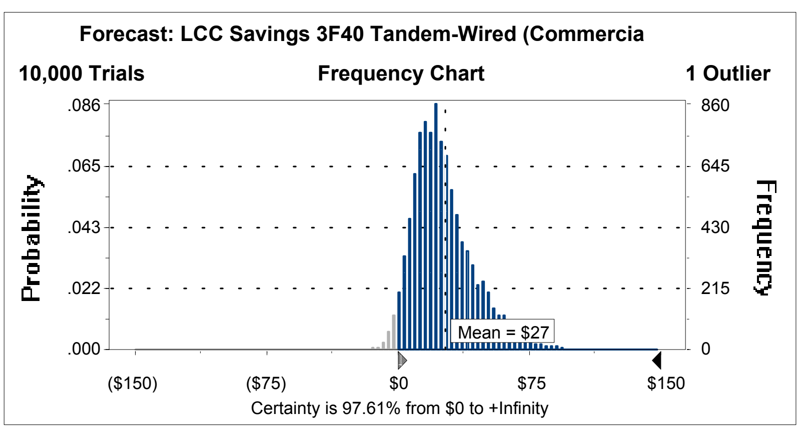

Figure 4.19 Life-Cycle Cost Savings for Tandem-Wired 3F32T8 ERS in Commercial Sector

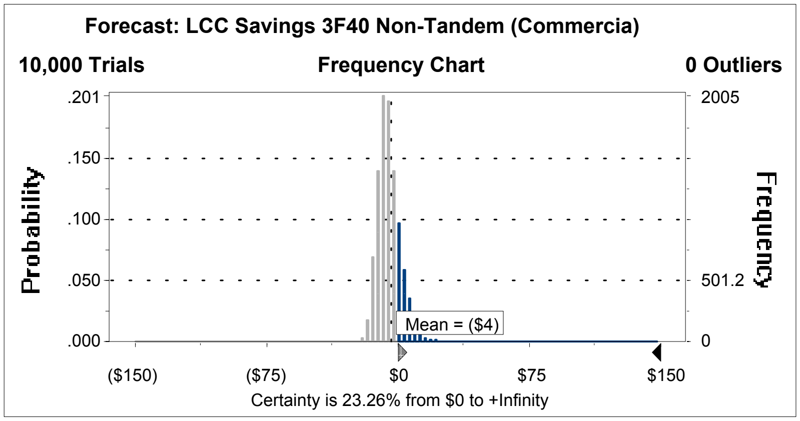

Figure 4.20 Life-Cycle Cost Savings for Non-Tandem-Wired 3F40T12 CC in Commercial Sector

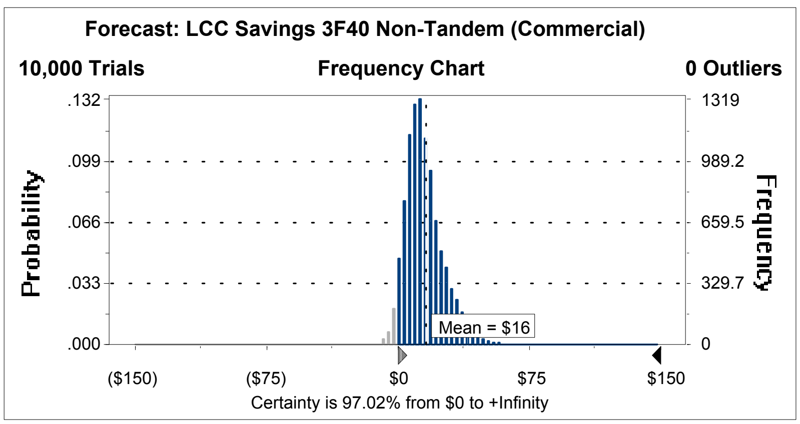

Figure 4.21 Life-Cycle Cost Savings for Non-Tandem-Wired 3F40T12 ERS in Commercial Sector

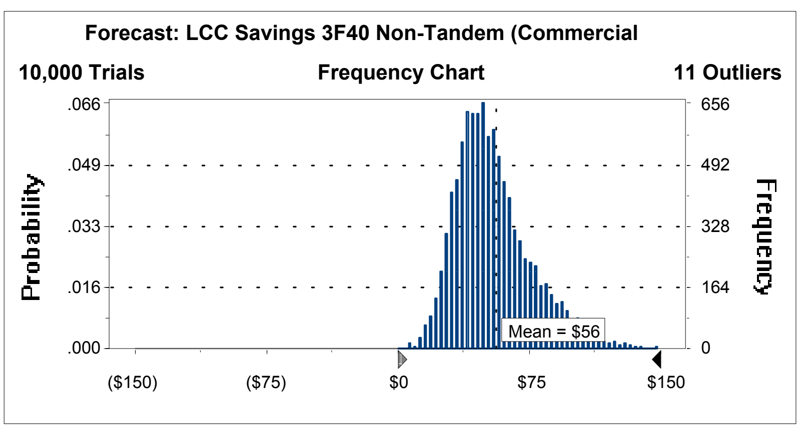

Figure 4.22 Life-Cycle Cost Savings for Non-Tandem-Wired 3F32T8 ERS in Commercial Sector

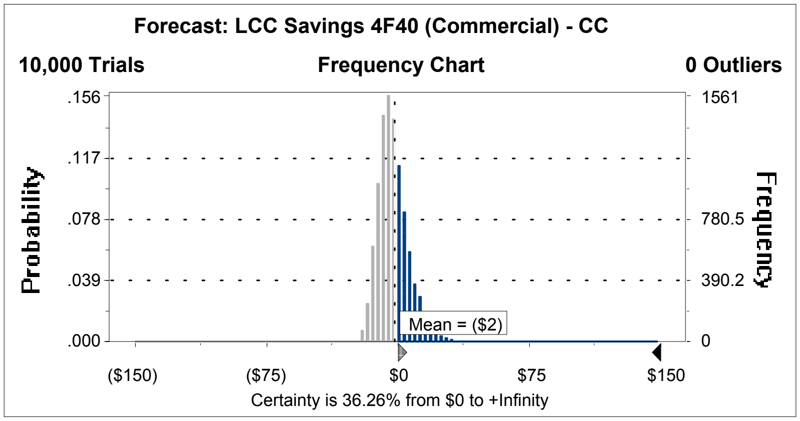

Figure 4.23 Life-Cycle Cost Savings for 4F40T12 CC in Commercial Sector

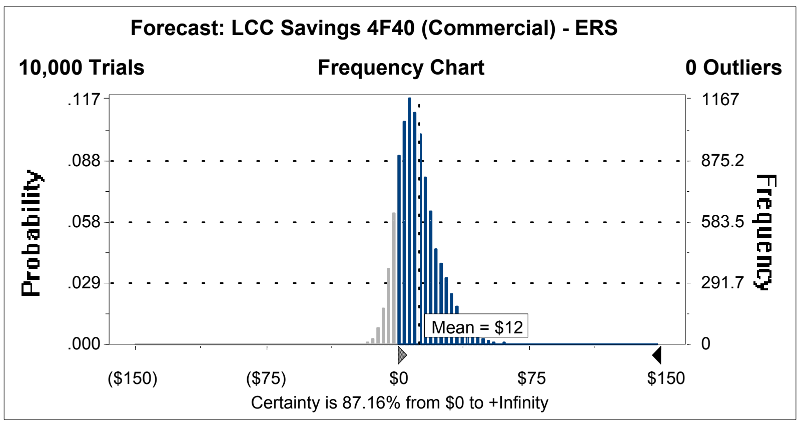

Figure 4.24 Life-Cycle Cost Savings for 4F40T12 ERS in Commercial Sector

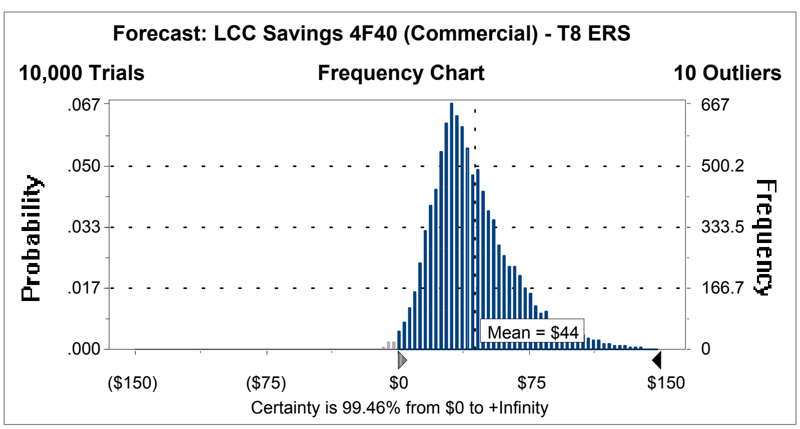

Figure 4.25 Life-Cycle Cost Savings for 4F32T8 ERS with Dual Switching Capability in Commercial Sector

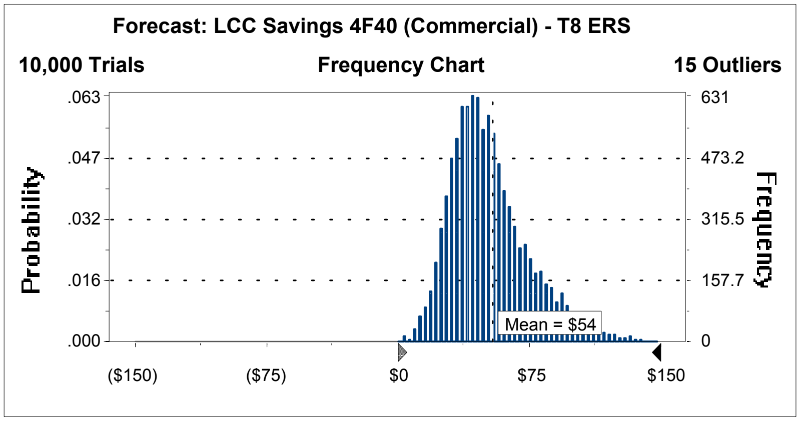

Figure 4.26 Life-Cycle Cost Savings for 4F32T8 ERS without Dual Switching Capability in Commercial Sector

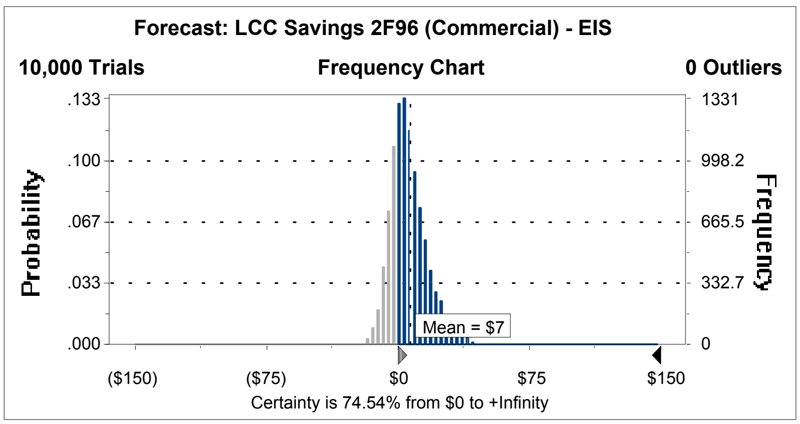

Figure 4.27 Life-Cycle Cost Savings for 2F96T12 EIS in Commercial Sector

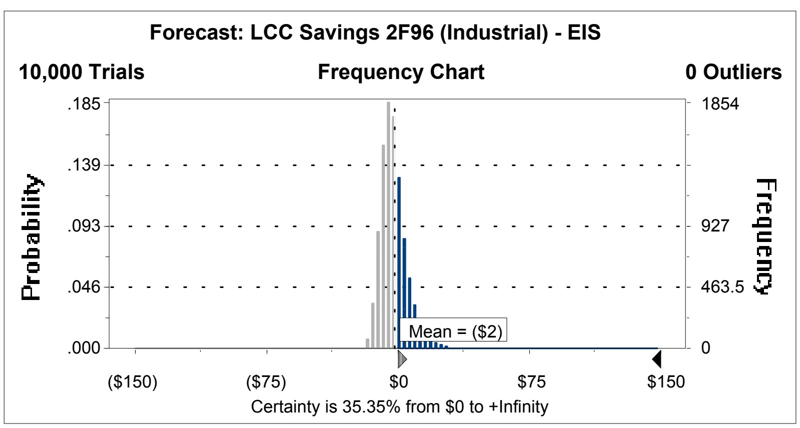

Figure 4.28 Life-Cycle Cost Savings for 2F96T12 EIS in Industrial Sector

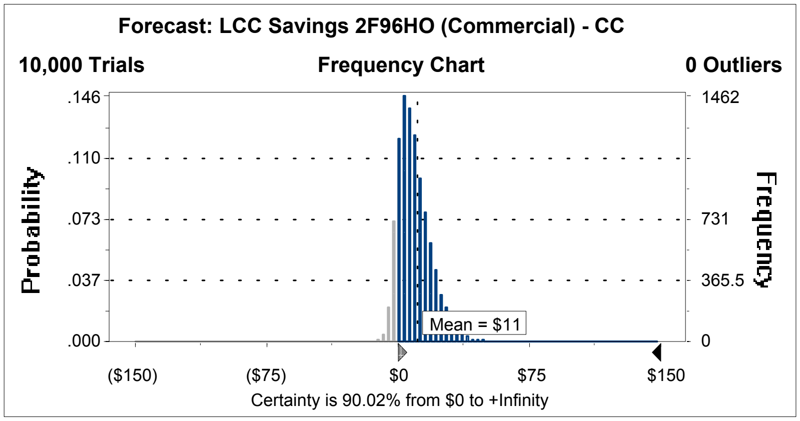

Figure 4.29 Life-Cycle Cost Savings for 2F96T12HO CC in Commercial Sector

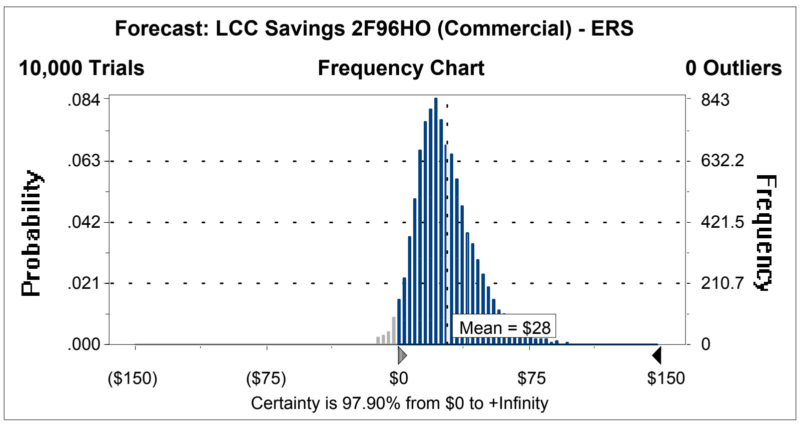

Figure 4.30 Life-Cycle Cost Savings for 2F96T12HO ERS in Commercial Sector

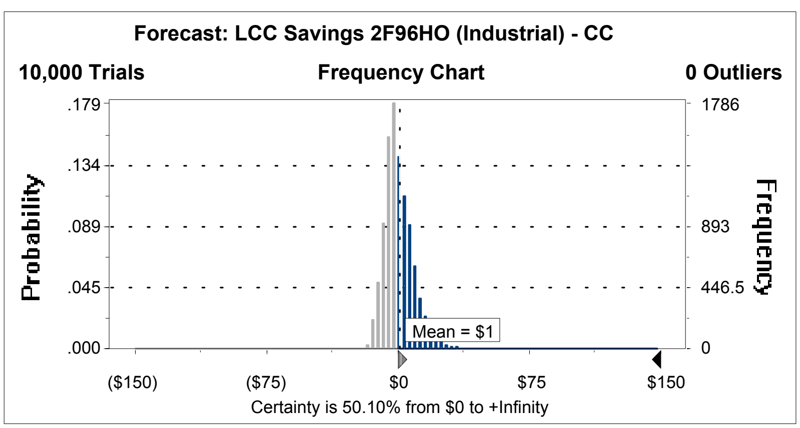

Figure 4.31 Life-Cycle Cost Savings for 2F96T12HO CC in Industrial Sector

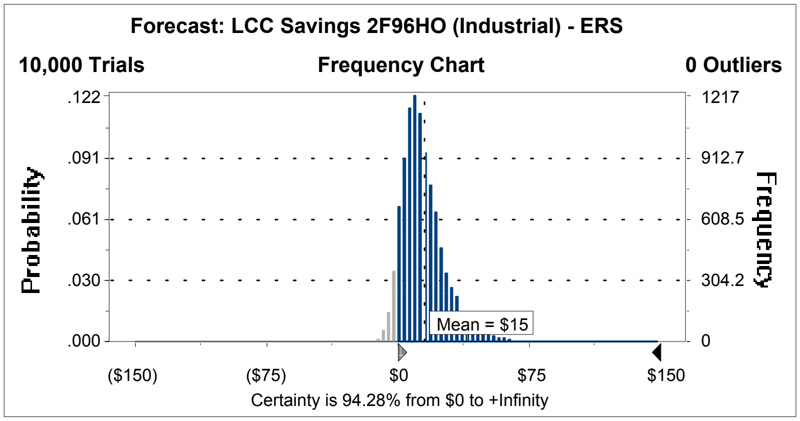

Figure 4.32 Life-Cycle Cost Savings for 2F96T12HO ERS in Industrial Sector

Energy Efficient T8 Magnetic Ballast Baseline. Table 4.4 and the following 5 figures present the results of an LCC analysis looking at switching from a T8 magnetic ballast baseline to a more energy efficient T8 ballast for 1 and 2 lamp fixtures. For the EIS and CC ballasts, there is a reduction in lamp lifetime from 19,000 hours to 14,000 and 16,150 hours, respectively that is taken into account in the LCC analysis. The ballast prices used for this LCC analysis are shown below. The magnetic and cathode cutout ballast prices come from the July, 1997 ballast report. The ERS prices are shown in Chapter 3 and the EIS prices are assumed to be $1 less than the ERS ballast prices.

Table 4.4 Summary of Delta LCC* Results Using an EEM T8 Ballast as a Baseline

Product Class	**Design Option**	**Sector**	**Delta LCC**		
			Mean (1997$)	**% of Baseline LCC**	**% Reduced** [**] LCC
1F32					
	T8 ERS	Commercial	6	5%	96%
	T8 EIS	Commercial	1	1%	54%
2F32					
	T8 CC	Commercial	0	0%	52%
	T8 ERS	Commercial	9	4%	97%
	T8 EIS	Commercial	6	3%	79%

* A positive Delta LCC implies a LCC savings whereas a negative number implies an increase in LCC.
** % ballasts with reduced life cycle cost.

Table 4.5 T8 Ballast Prices for Use with T8 Ballast LCC Analysis

	Ballast Price (1997$)			
Product Class	Baseline EEM	CC	ERS	EIS
1-lamp ballast	15.96	N/A	20.10	19.10
2-lamp ballast	15.60	19.24	21.54	20.54

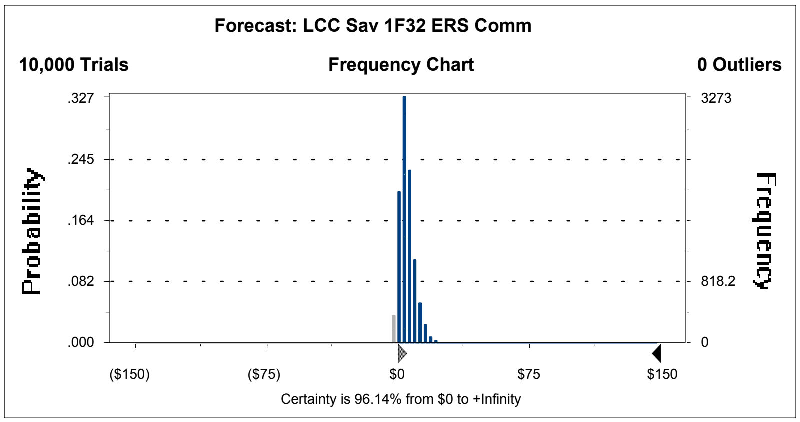

Figure 4.33 Life-Cycle Cost Savings for 1F32T8 ERS in Commercial Sector

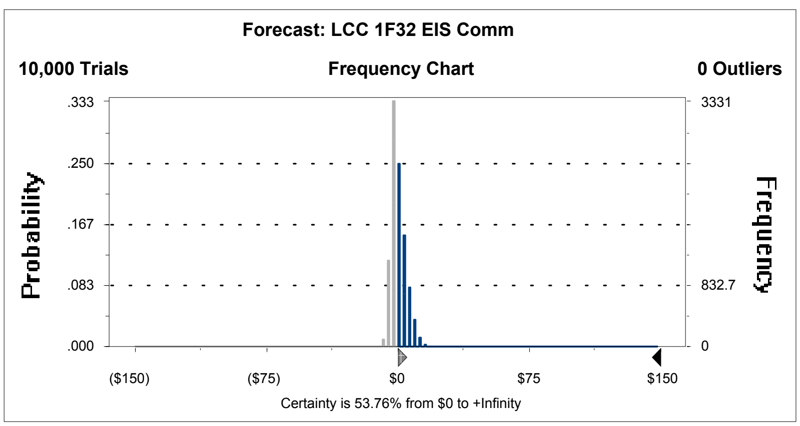

Figure 4.34 Life-Cycle Cost Savings for 1F32T8 EIS in Commercial Sector

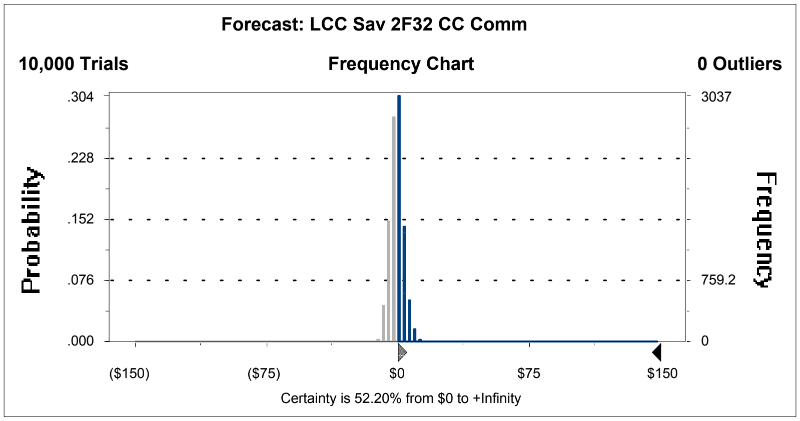

Figure 4.35 Life-Cycle Cost Savings for 2F32T8 CC in Commercial Sector

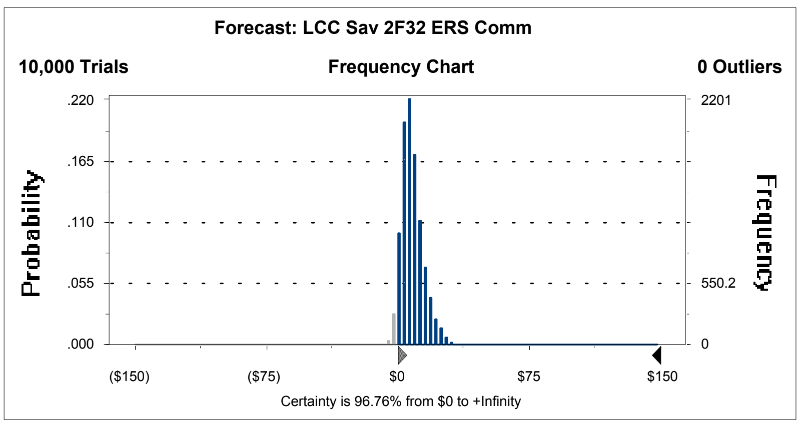

Figure 4.36 Life-Cycle Cost Savings for 2F32T8 ERS in Commercial Sector

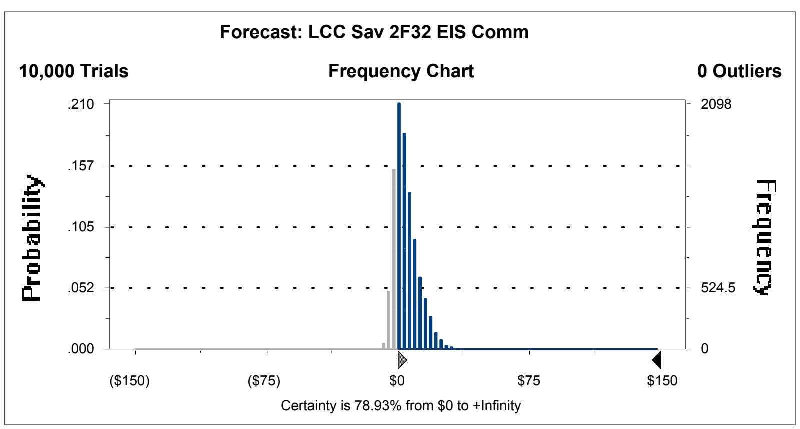

Figure 4.37 Life-Cycle Cost Savings for 2F32T8 EIS in Commercial Sector

4.2 PAYBACK PERIODS BY ENERGY-EFFICIENCY LEVEL

The payback period (PAY) is the amount of time needed to recover through lower operating costs, ΔOC, the additional consumer investment, ΔPC, in increased efficiency. PAY is found by solving the equation:

$$\Delta PC + \sum_{t=1}^{PAY} \Delta OC_t = 0 \tag{4.4}$$

for *PAY*. In general, *PAY* is found by interpolating between the two years when the expression in Eq. 4.4 changes sign. If the operating cost is constant, the equation has the simple solution:

$$PAY = -\frac{\Delta PC}{\Delta OC} \tag{4.5}$$

Numerically, the payback period is the ratio of the difference in purchase (and installation) price between the base and the energy-efficient models to the decrease in annual operating expenditures (including maintenance). Annual operating costs for ballasts include annual lamp replacement cost plus annual electricity cost.

$$PAY = -\frac{\Delta PC}{\Delta EC + \Delta LRC} \tag{4.6}$$

where EC is the electricity cost and LRC is the lamp replacement cost. Because the life of a lamp with a CC or EIS ballast is less than that of a lamp with an EEM or ERS ballast, lamp replacement costs may occur at different times during the life of the ballast, depending upon the ballast-lamp combination. A longer lamp life results in a lower operating cost. In order to account for differences in lamp life, the cost of lamp replacement has been divided over the life of the lamp so that an annual lamp replacement cost (LRC) is equal to:

$$LRC = \frac{Cost\ of\ Lamp\ Replacement}{Lamp\ Life} \tag{4.7}$$

For example, consider the payback calculation for going from an EEM to a CC ballast for the 2F40T12/ES case. Suppose the ballast equipment and labor costs are \$34.54 and \$39.43 for the EEM and CC options, respectively. The annual electricity costs are \$19.55 and \$17.81, respectively, and the lamp equipment and labor cost is \$14.78 for each. The lamp service life for EEM ballasts is 5.28 yrs and for CC it is 4.49 yrs. Thus, we have ΔPC = \$-4.89, ΔEC = \$1.74/yr and

$$\Delta LRC = \frac{14.78}{5.28} - \frac{14.78}{4.49} = -\$0.49/yr$$

This results in a payback period of equation as follows:

$$PAY = -\frac{-4.89}{1.74 - 0.49} = 3.9 yrs$$

Note there has been no discounting of lamp costs or electricity costs in this formulation of payback period.

Payback periods are expressed in years. A payback period of three years means that the increased purchase price for an energy-efficient ballast relative to a baseline ballast is recovered in approximately three years because of lower operating expenses. Payback periods greater than the life of the product mean that the increased purchase price is not recovered through reduced operating expenses.

4.2.1 Payback Period Results

The output from the payback period analysis is a distribution of paybacks that may contain negative values. Occasionally, very large negative values (for cathode-cutout ballasts) distort the mean payback period value. For this reason, we present the median payback period. Therefore, for the 10,000 cases analyzed for each lamp/ballast combination, 5000 have payback periods below and 5,000 have payback periods above the median values shown in the table. It is possible for the median payback period to be negative if the first cost of the ballast plus lamp is lower for the more efficient technology than for the baseline. We interpret negative payback periods (e.g., for three-lamp non tandem, T8 ERS and 4 lamp T8 ERS) as essentially immediate paybacks. A summary listing the median payback period for each lamp/ballast combination is presented in Table 4.6. The corresponding probability distributions are presented in Figures 4.38 to 4.59. Table 4.7 and Figures 4.60 to 4.64 present the summary results and corresponding probability distributions using the energy efficient T8 magnetic ballast as the baseline. The last column in the summary table presents the percent of cases for which the median payback period is less than 15 years. A 15-year period was chosen because it approximates average ballast life for most of the lamp/ballast combinations.

Table 4.6 Summary of Payback Periods Using the T12 EEM as the Baseline

Product Class	Design Option	Sector	Median Payback Period (yrs)	% With Payback Less Than 15 yrs
1F40				
	T12 CC	Commercial	24.8	26
	T12 ERS	Commercial	6.4	94
	T8 ERS	Commercial	2.7	99
2F40				
	T12 CC	Commercial	10.7	71
	T12 ERS	Commercial	5.4	96
	T8 ERS	Commercial	3.1	99
3F40				
Tandem-Wired	T12 CC	Commercial	9.9	76
	T12 ERS	Commercial	6.4	93
	T8 ERS	Commercial	3.1	99
Not Tandem-Wired	T12 CC	Commercial	11.5	68
	T12 ERS	Commercial	3.3	99
	T8 ERS	Commercial	0.0	100
4F40				
	T12 CC	Commercial	9.3	80
	T12 ERS	Commercial	4.8	97
Dual Switching	T8 ERS	Commercial	1.9	100
w/o Dual Switching	T8 ERS	Commercial	0.4	100
2F96				
	T12 EIS	Commercial	5.9	94
	T12 EIS	Industrial	8.8	84
2F96HO				
	T12 CC	Commercial	2.1	98
	T12 ERS	Commercial	2.4	99
	T12 CC	Industrial	5.4	76
	T12 ERS	Industrial	3.1	99

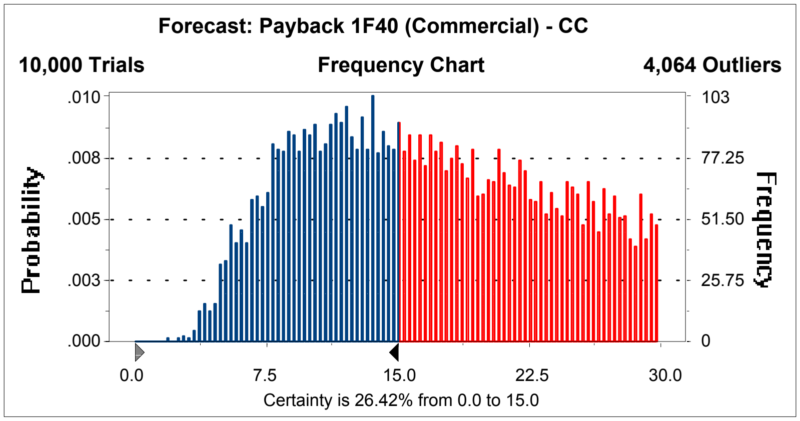

Figure 4.38 Payback Distribution for 1F40T12 CC in Commercial Sector

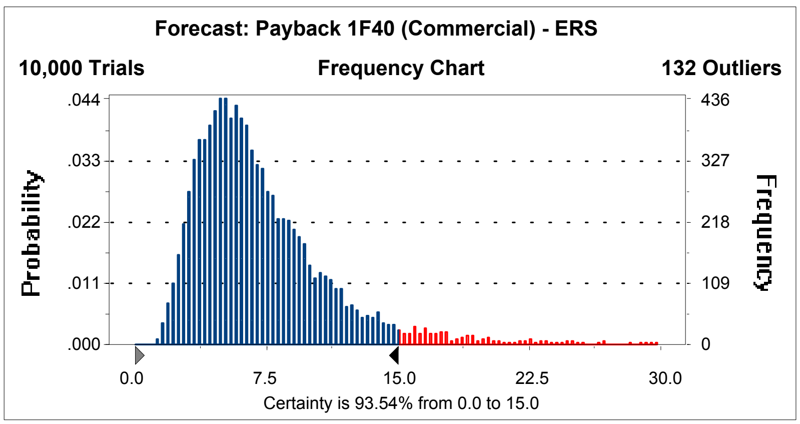

Figure 4.39 Payback Distribution for 1F40T12 ERS in Commercial Sector

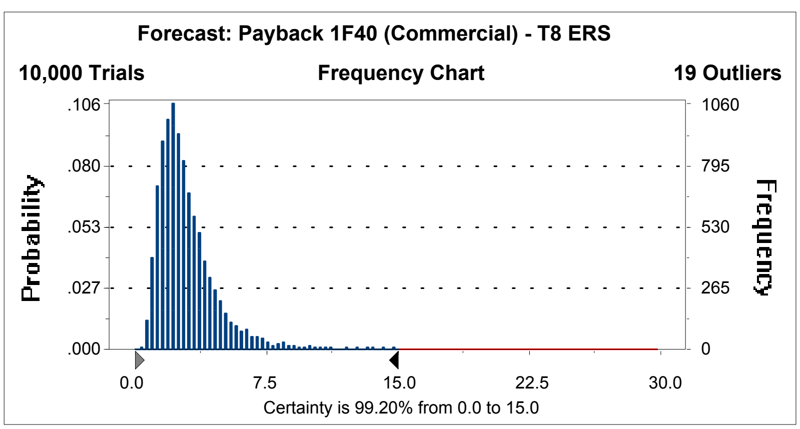

Figure 4.40 Payback Distribution for 1F32T8 ERS in Commercial Sector

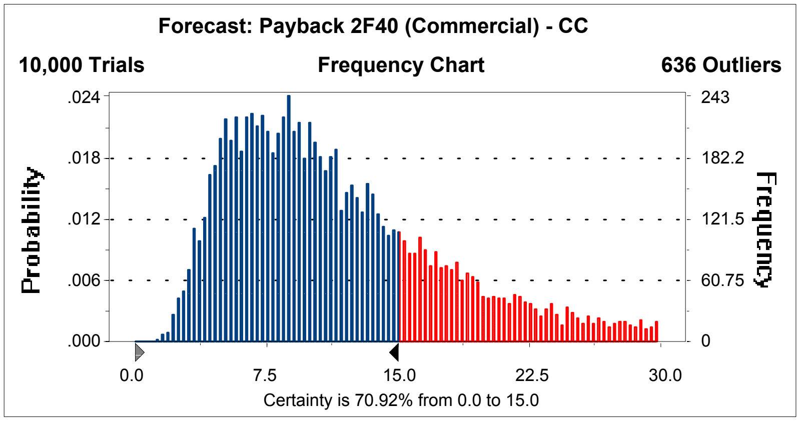

Figure 4.41 Payback Distribution for 2F40T12 CC in Commercial Sector

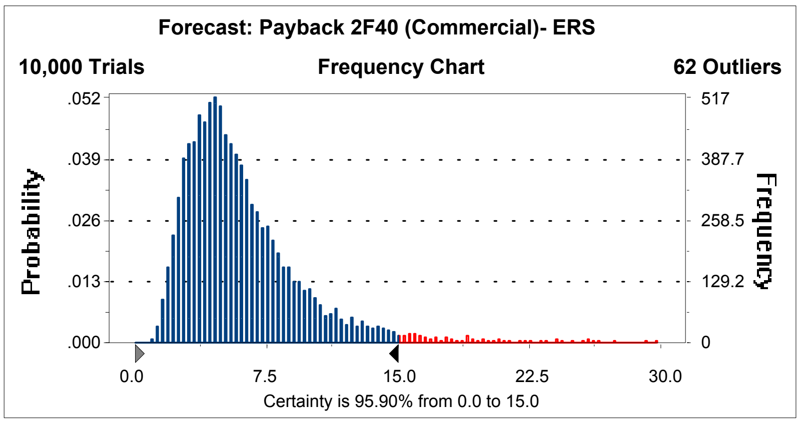

Figure 4.42 Payback Distribution for 2F40T12 ERS in Commercial Sector

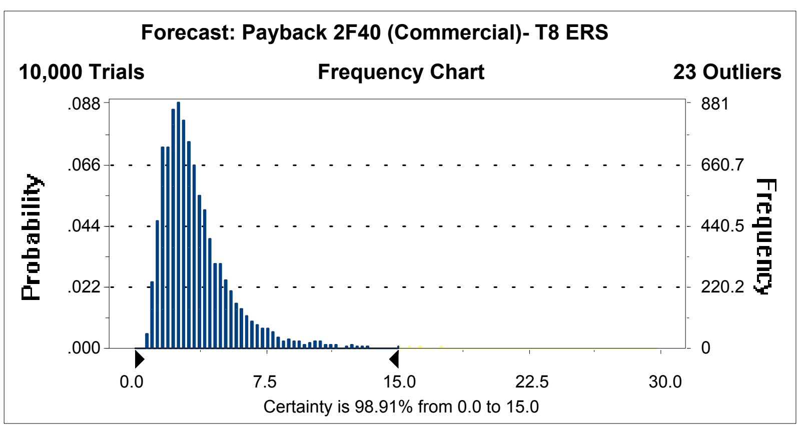

Figure 4.43 Payback Distribution for 2F32T8 ERS in Commercial Sector

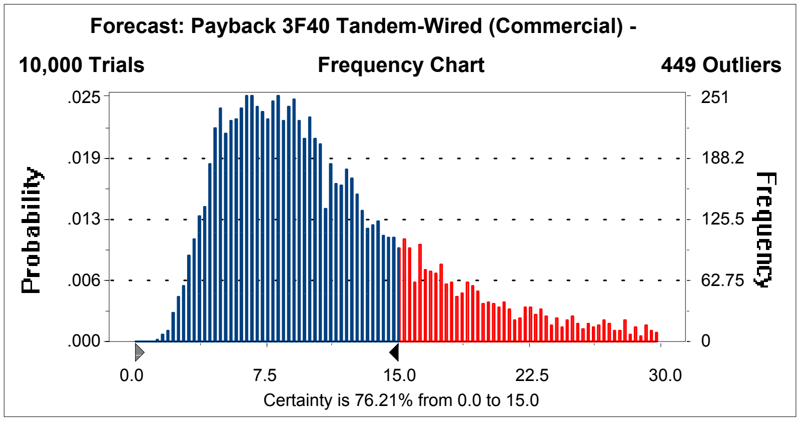

Figure 4.44 Payback Distribution for Tandem-Wired 3F40T12 CC in Commercial Sector

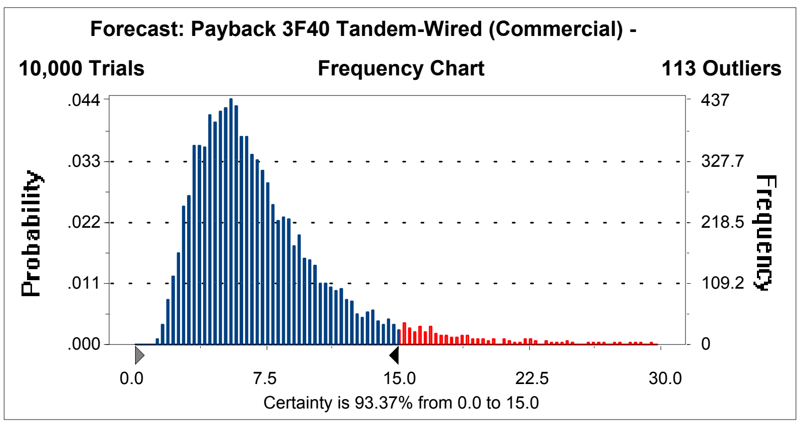

Figure 4.45 Payback Distribution for Tandem-Wired 3F40T12 ERS in Commercial Sector

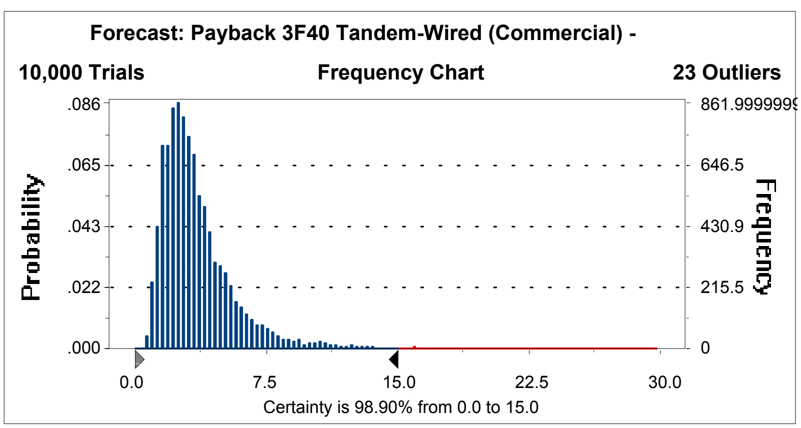

Figure 4.46 Payback Distribution for Tandem-Wired 3F32T8 ERS in Commercial Sector

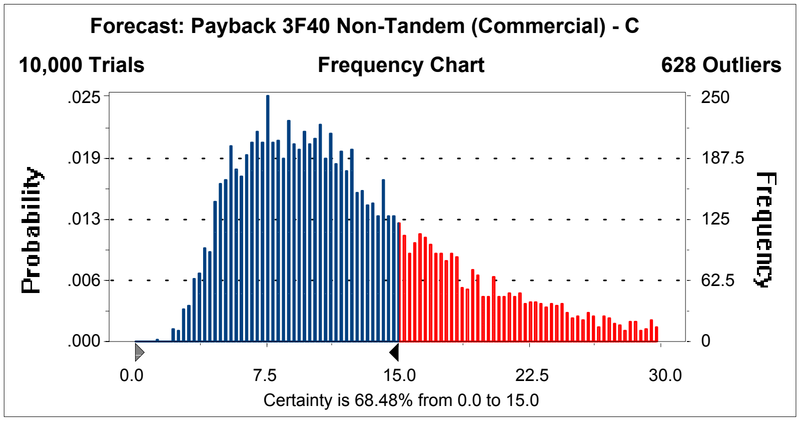

Figure 4.47 Payback Distribution for Non-Tandem-Wired 3F40T12 CC in Commercial Sector

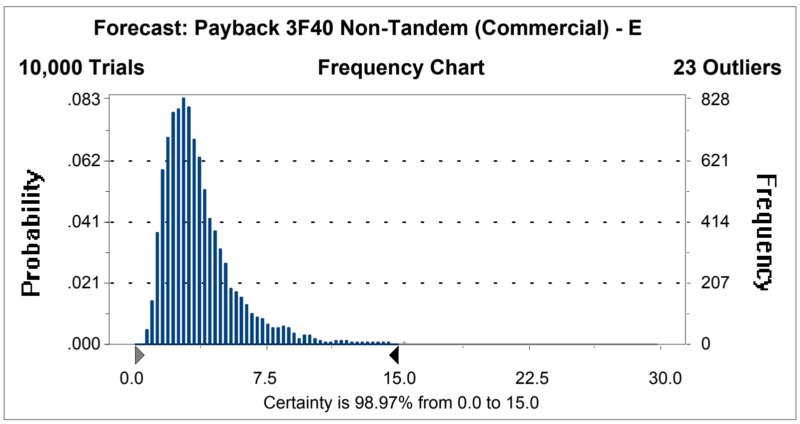

Figure 4.48 Payback Distribution for Non-Tandem-Wired 3F40T12 ERS in Commercial Sector

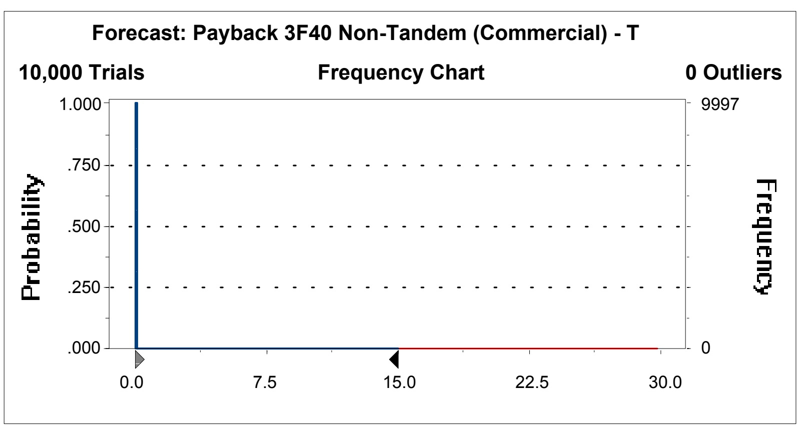

Figure 4.49 Payback Distribution for Non-Tandem-Wired 3F32T8 ERS in Commercial Sector

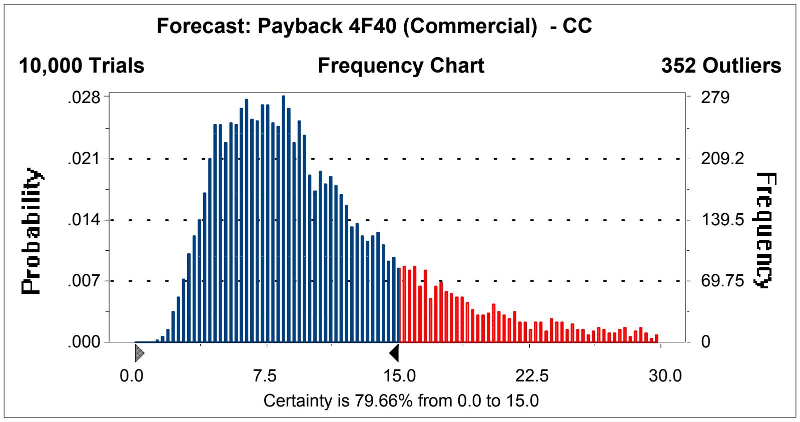

Figure 4.50 Payback Distribution for 4F40T12 CC in Commercial Sector

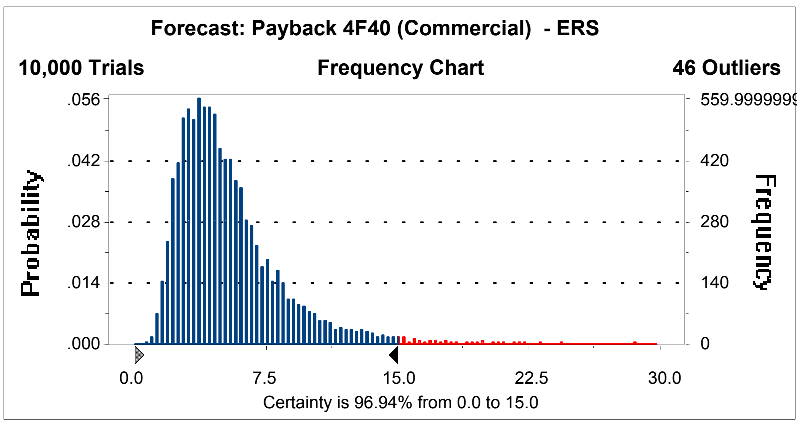

Figure 4.51 Payback Distribution for 4F40T12 ERS in Commercial Sector

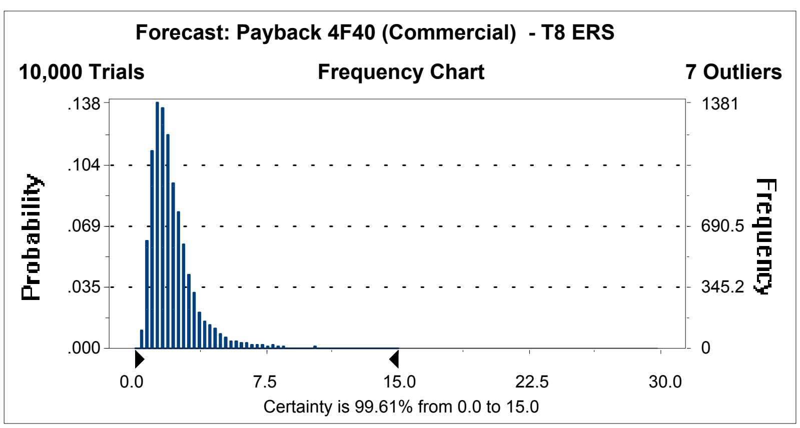

Figure 4.52 Payback Distribution for 4F32T8 ERS with Dual Switching Capability in Commercial Sector

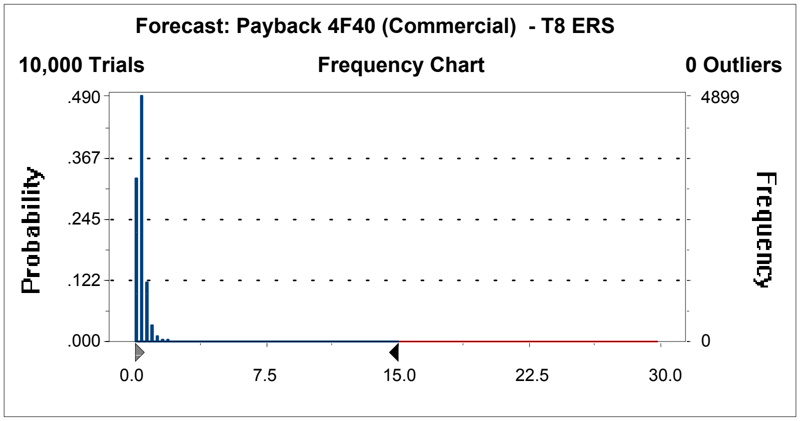

Figure 4.53 Payback Distribution for 4F32T8 ERS without Dual Switching Capability in Commercial Sector

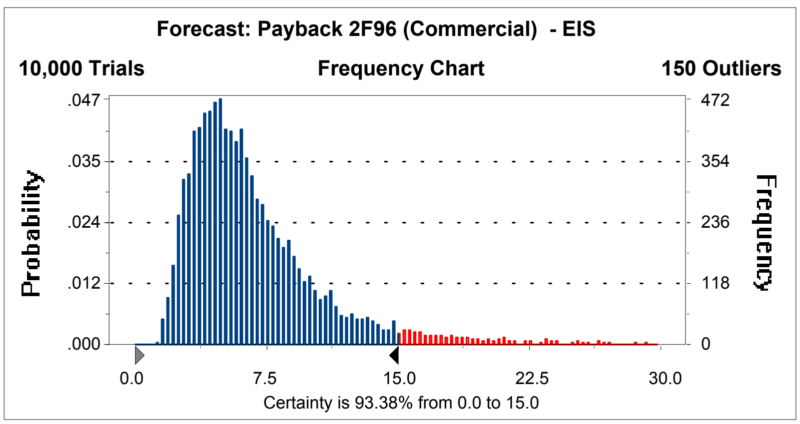

Figure 4.54 Payback Distribution for 2F96T12 EIS in Commercial Sector

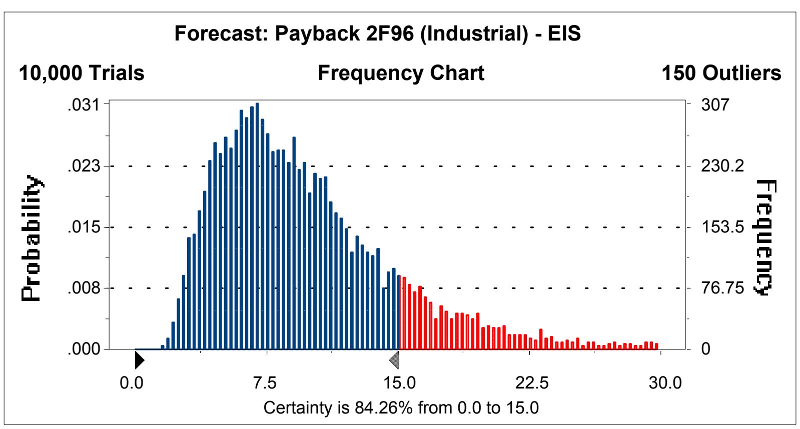

Figure 4.55 Payback Distribution for 2F96T12 EIS in Industrial Sector

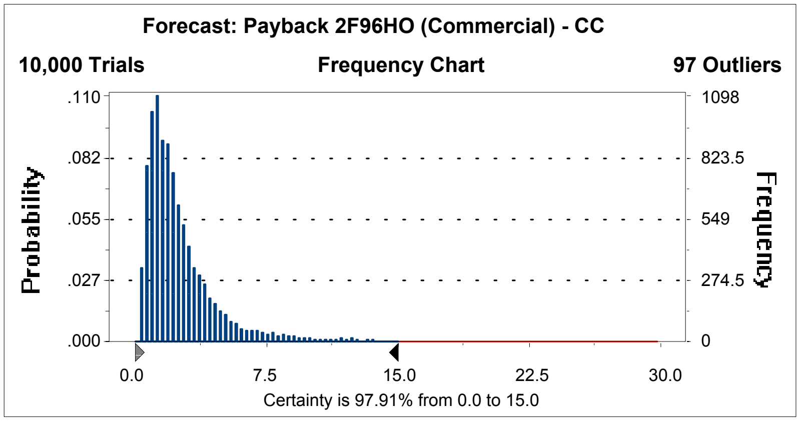

Figure 4.56 Payback Distribution for 2F96T12HO CC in Commercial Sector

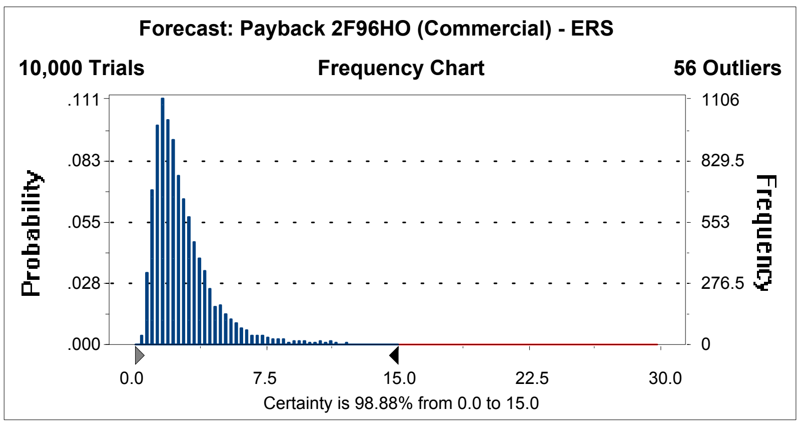

Figure 4.57 Payback Distribution for 2F96T12HO ERS in Commercial Sector

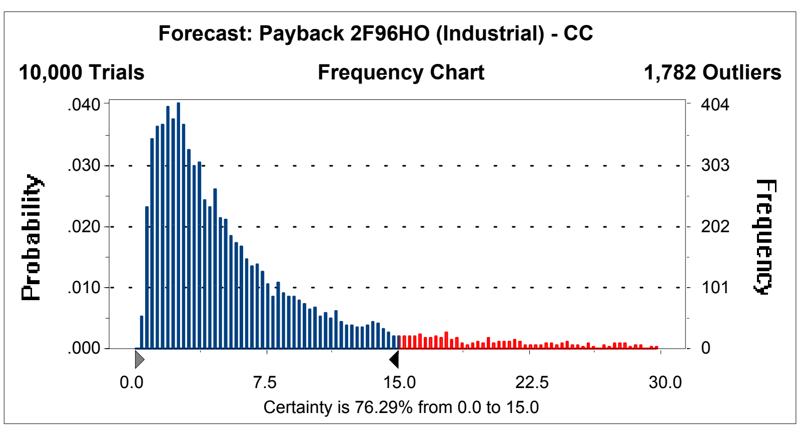

Figure 4.58 Payback Distribution for 2F96T12HO CC in Industrial Sector

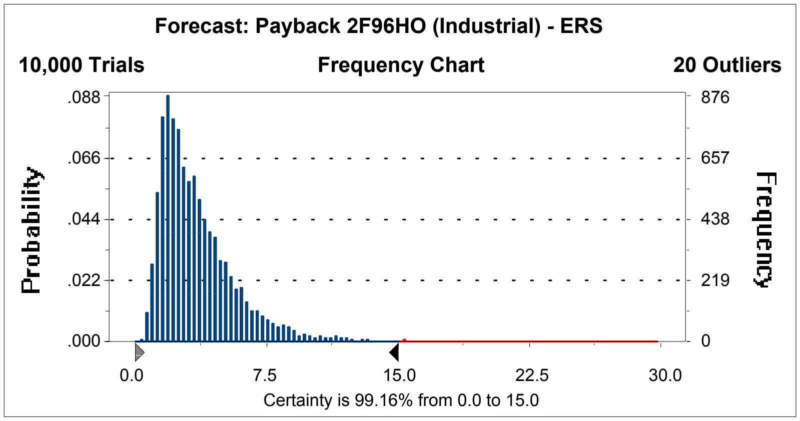

Figure 4.59 Payback Distribution for 2F96T12HO ERS in Industrial Sector

Table 4.7 Summary of Payback Periods Using a T8 EEM Ballast as the Baseline

Product Class	Design Option	Sector	Median Payback Period (yrs)	% With Payback Less Than 15 yrs
1F32				
	T8 ERS	Commercial	3.4	99%
	T8 EIS	Commercial	6.6	81%
2F32				
	T8 CC	Commercial	8.2	78%
	T8 ERS	Commercial	3.3	100%
	T8 EIS	Commercial	4.0	95%

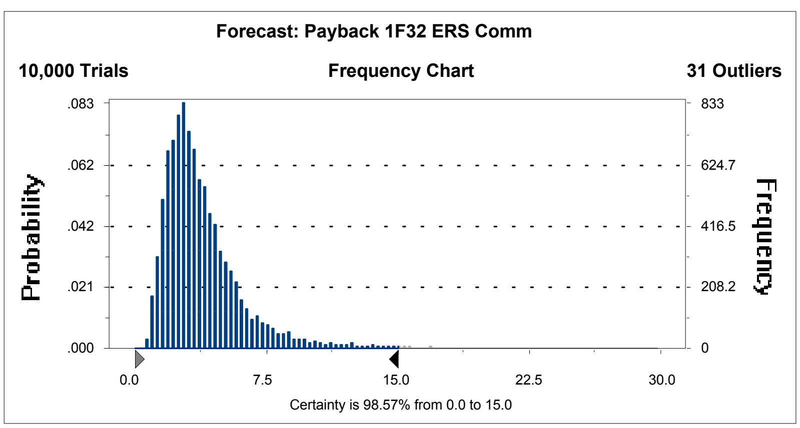

Figure 4.60 Payback Distribution for 1F32T8 ERS in Commercial Sector

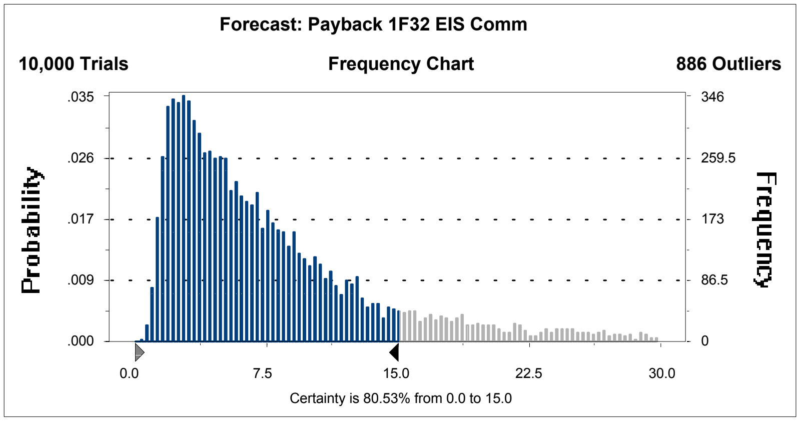

Figure 4.61 Payback Distribution for 1F32T8 EIS in Commercial Sector

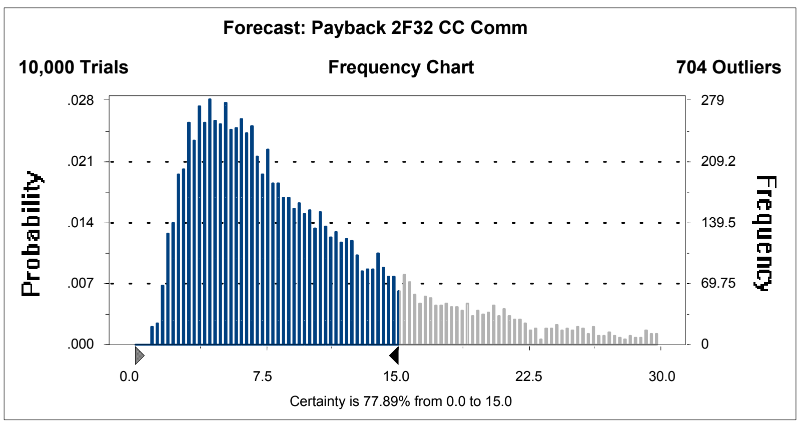

Figure 4.62 Payback Distribution for 2F32T8 CC in Commercial Sector

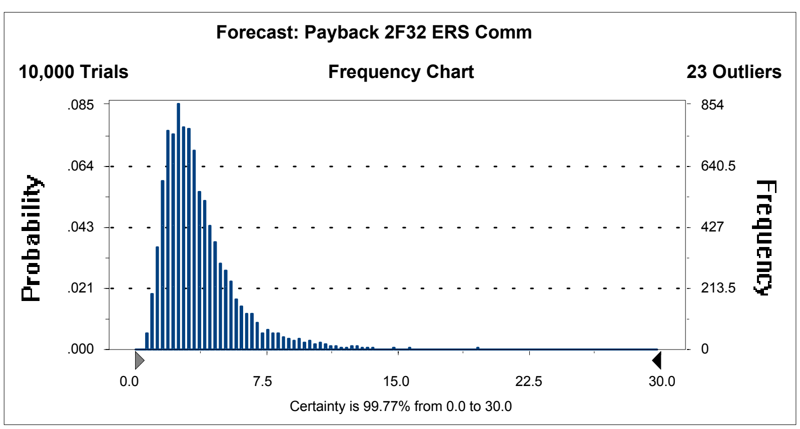

Figure 4.63 Payback Distribution for 2F32T8 ERS in Commercial Sector

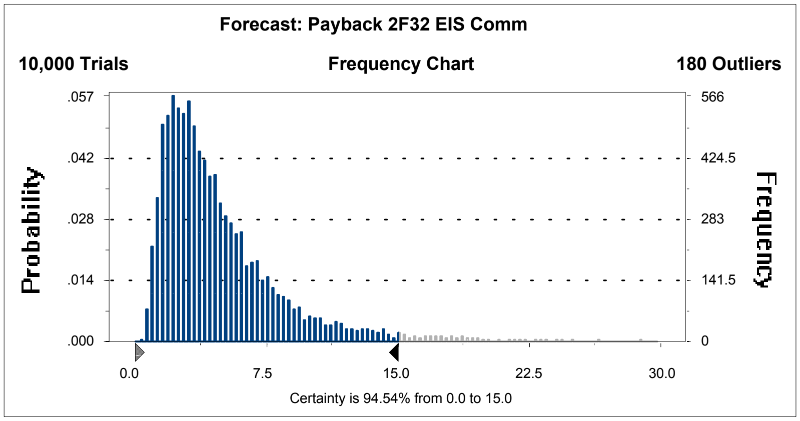

Figure 4.64 Payback Distribution for 2F32T8 EIS in Commercial Sector

4.3 SENSITIVITY ANALYSIS

In order to observe the sensitivity of LCC to discount rates and electricity prices, we performed additional analyses. For discount rates, we recalculated the LCC savings using a low (4%) and a high (15%) estimate of the consumer discount rate. Tables 4.8 and 4.9 show the results of this sensitivity analysis for each case respectively.

For electricity prices, we recalculated the LCC savings and the Payback using the both the AEO 1999 High Economic Growth Forecast, and the AEO 1999 Low Economic Growth Forecast. Tables 4.10 and 4.11 show the LCC and Payback results for the High Growth Forecast. Tables 4.12 and 4.13 show the results for the Low Growth Forecast.

Table 4.8 Summary of Delta LCC* Sensitivity Results with 4% Discount Rate

Product Class	Design Option	Sector	Delta LCC		
			Mean (1997$)	**% of Baseline LCC**	**% Reduced** LCC**
1F40					
	T12 CC	Commercial	-4	-3%	18%
	T12 ERS	Commercial	9	6%	87%
	T8 ERS	Commercial	24	15%	100%
2F40					
	T12 CC	Commercial	0	0%	49%
	T12 ERS	Commercial	11	5%	93%
	T8 ERS	Commercial	27	11%	99%
3F40					
Tandem-Wired	T12 CC	Commercial	1	0%	52%
	T12 ERS	Commercial	12	4%	86%
	T8 ERS	Commercial	39	12%	99%
Not Tandem-Wired	T12 CC	Commercial	-1	0%	42%
	T12 ERS	Commercial	24	7%	99%
	T8 ERS	Commercial	72	21%	100%
4F40					
	T12 CC	Commercial	3	1%	56%
	T12 ERS	Commercial	21	5%	96%
Tandem-Wired***	T8 ERS	Commercial	61	14%	100%
Not Tandem-Wired	T8 ERS	Commercial	70	17%	100%
2F96					
	T12 EIS	Commercial	15	4%	91%
	T12 EIS	Industrial	3	1%	59%
2F96HO					
	T12 CC	Commercial	14	2%	91%
	T12 ERS	Commercial	40	6%	99%
	T12 CC	Industrial	2	0%	54%
	T12 ERS	Industrial	22	4%	97%

* A positive Delta LCC implies a LCC savings whereas a negative number implies an increase in LCC.
** % ballasts with reduced life-cycle costs.
*** 4F32T8 ERS ballast with Dual Switching includes a $10 incremental increase in materials and labor

Table 4.9 Summary of Delta LCC* Sensitivity Results with 15% Discount Rate

Product Class	**Design Option**	**Sector**	**Delta LCC**		
			Mean (1997$)	**% of Baseline LCC**	**% Reduced** ** LCC
1F40					
	T12 CC	Commercial	-5	-5%	1%
	T12 ERS	Commercial	-1	-1%	35%
	T8 ERS	Commercial	9	9%	93%
2F40					
	T12 CC	Commercial	-4	-3%	12%
	T12 ERS	Commercial	1	1%	50%
	T8 ERS	Commercial	10	7%	90%
3F40					
Tandem-Wired	T12 CC	Commercial	-5	-3%	13%
	T12 ERS	Commercial	-2	-1%	36%
	T8 ERS	Commercial	14	7%	90%
Not Tandem-Wired	T12 CC	Commercial	-8	-4%	7%
	T12 ERS	Commercial	8	4%	86%
	T8 ERS	Commercial	40	19%	100%
4F40					
	T12 CC	Commercial	-7	-3%	15%
	T12 ERS	Commercial	3	1%	61%
Tandem-Wired***	T8 ERS	Commercial	27	11%	97%
Not Tandem-Wired	T8 ERS	Commercial	37	15%	100%
2F96					
	T12 EIS	Commercial	0	0%	43%
	T12 EIS	Industrial	-6	-3%	13%
2F96HO					
	T12 CC	Commercial	6	1%	85%
	T12 ERS	Commercial	17	4%	93%
	T12 CC	Industrial	0	0%	41%
	T12 ERS	Industrial	8	2%	83%

* A positive Delta LCC implies a LCC savings whereas a negative number implies an increase in LCC.
** % ballasts with reduced life-cycle costs.
*** 4F32T8 ERS ballast with Dual Switching includes a $10 incremental increase in materials and labor.

Table 4.10 Summary of Delta LCC* Sensitivity Results using AEO 1999 High Growth Forecast

Product Class	Design Option	Sector	Delta LCC		
			Mean (1997$)	% of Baseline LCC	% Winners**
1F40					
	T12 CC	Commercial	-4	-3%	9%
	T12 ERS	Commercial	5	4%	73%
	T8 ERS	Commercial	18	13%	99%
2F40					
	T12 CC	Commercial	-1	-1%	35%
	T12 ERS	Commercial	7	4%	84%
	T8 ERS	Commercial	20	10%	98%
3F40					
Tandem-Wired	T12 CC	Commercial	-1	0%	38%
	T12 ERS	Commercial	6	2%	73%
	T8 ERS	Commercial	30	11%	98%
Not Tandem-Wired	T12 CC	Commercial	-3	1%	27%
	T12 ERS	Commercial	18	6%	98%
	T8 ERS	Commercial	59	20%	100%
4F40					
	T12 CC	Commercial	-1	0%	41%
	T12 ERS	Commercial	14	4%	90%
Dual Switching***	T8 ERS	Commercial			
w/o Dual Switching	T8 ERS	Commercial	57	16%	100%
2F96					
	T12 EIS	Commercial	8	1%	78%
	T12 EIS	Industrial	-1	0%	39%
2F96HO					
	T12 CC	Commercial	12	2%	92%
	T12 ERS	Commercial	30	5%	98%
	T12 CC	Industrial	2	0%	54%
	T12 ERS	Industrial	17	4%	95%

* A positive Delta LCC implies a LCC savings whereas a negative number implies an increase in LCC.
** % ballasts with reduced life-cycle costs (winners).
*** 4F32T8 ERS ballast with Dual Switching includes a $10 incremental increase in purchase price.

Table 4.11 Summary of Payback Sensitivity using AEO 1999 High Growth Forecast

Product Class	Design Option	Sector	Median Payback Period (yrs)	% With Payback Less Than 15 yrs
1F40				
	T12 CC	Commercial	23.5	29%
	T12 ERS	Commercial	6.3	93%
	T8 ERS	Commercial	2.6	99%
2F40				
	T12 CC	Commercial	10.3	74%
	T12 ERS	Commercial	5.3	96%
	T8 ERS	Commercial	3.0	99%
3F40				
Tandem-Wired	T12 CC	Commercial	9.6	79%
	T12 ERS	Commercial	6.2	94%
	T8 ERS	Commercial	3.0	99%
Not Tandem-Wired	T12 CC	Commercial	11.1	71%
	T12 ERS	Commercial	3.2	99%
	T8 ERS	Commercial	0.0	100%
4F40				
	T12 CC	Commercial	9.1	82%
	T12 ERS	Commercial	4.7	97%
Dual Switching	T8 ERS	Commercial	1.8	100%
w/o Dual Switching	T8 ERS	Commercial	0.4	100%
2F96				
	T12 EIS	Commercial	5.7	94%
	T12 EIS	Industrial	8.6	85%
2F96HO				
	T12 CC	Commercial	2.0	98%
	T12 ERS	Commercial	2.3	99%
	T12 CC	Industrial	5.0	78%
	T12 ERS	Industrial	3.1	99%

Table 4.12 Summary of Delta LCC* Sensitivity Results using AEO 1999 Low Growth Forecast

Product Class	Design Option	Sector	Delta LCC		
			Mean (1997$)	**% of Baseline LCC**	**% Winners****
1F40					
	T12 CC	Commercial	-5	-4%	6%
	T12 ERS	Commercial	3	2%	61%
	T8 ERS	Commercial	15	12%	98%
2F40					
	T12 CC	Commercial	-3	2%	25%
	T12 ERS	Commercial	5	3%	76%
	T8 ERS	Commercial	16	9%	97%
3F40					
Tandem-Wired	T12 CC	Commercial	-3	-1%	28%
	T12 ERS	Commercial	3	1%	61%
	T8 ERS	Commercial	24	10%	97%
Not Tandem-Wired	T12 CC	Commercial	-5	2%	18%
	T12 ERS	Commercial	14	5%	96%
	T8 ERS	Commercial	52	19%	100%
4F40					
	T12 CC	Commercial	-3	-1%	30%
	T12 ERS	Commercial	10	3%	83%
Dual Switching***	T8 ERS	Commercial	40	12%	99%
w/o Dual Switching	T8 ERS	Commercial	49	15%	100%
2F96					
	T12 EIS	Commercial	6	2%	69%
	T12 EIS	Industrial	-2	-1%	31%
2F96HO					
	T12 CC	Commercial	9	2%	86%
	T12 ERS	Commercial	26	5%	97%
	T12 CC	Industrial	0	0%	45%
	T12 ERS	Industrial	14	3%	93%

* A positive Delta LCC implies a LCC savings whereas a negative number implies an increase in LCC.
** % ballasts with reduced life-cycle costs (winners).
*** 4F32T8 ERS ballast with Dual Switching includes a $10 incremental increase in purchase price.

Table 4.13 Summary of Payback Sensitivity using AEO 1999 Low Growth Forecast

Product Class	Design Option	Sector	Median Payback Period (yrs)	% With Payback Less Than 15 yrs
1F40				
	T12 CC	Commercial	27.8	24
	T12 ERS	Commercial	6.7	92
	T8 ERS	Commercial	2.8	99
2F40				
	T12 CC	Commercial	11.6	66
	T12 ERS	Commercial	5.7	95
	T8 ERS	Commercial	3.3	99
3F40				
Tandem-Wired	T12 CC	Commercial	10.6	72
	T12 ERS	Commercial	6.7	93
	T8 ERS	Commercial	3.3	99
Not Tandem-Wired	T12 CC	Commercial	12.3	64
	T12 ERS	Commercial	3.5	99
	T8 ERS	Commercial	0.0	100
4F40				
	T12 CC	Commercial	10.0	76
	T12 ERS	Commercial	5.1	96
Dual Switching	T8 ERS	Commercial	2.0	100
w/o Dual Switching	T8 ERS	Commercial	0.4	100
2F96				
	T12 EIS	Commercial	6.1	93
	T12 EIS	Industrial	9.1	83
2F96HO				
	T12 CC	Commercial	2.3	98
	T12 ERS	Commercial	2.5	99
	T12 CC	Industrial	6.0	73
	T12 ERS	Industrial	3.2	99