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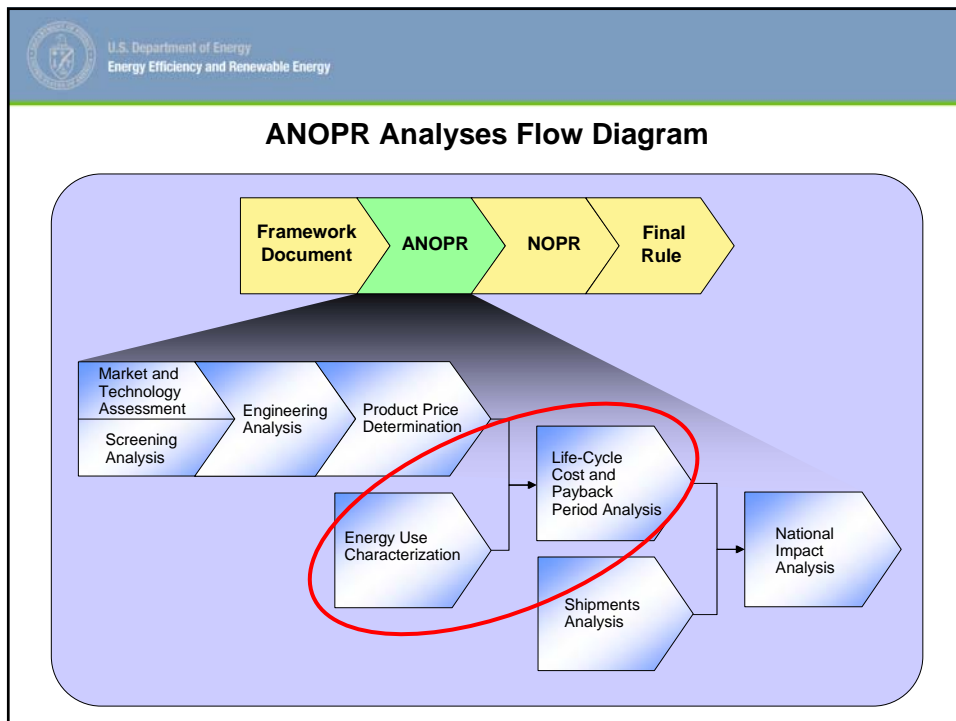
**Energy Conservation Standards for
General Service Fluorescent Lamps and
Incandescent Reflector Lamps**


ANOPR Public Meeting

Life-Cycle Cost Analysis

**Building Technologies Program
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy**

March 10-11, 2008




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Purpose

- **Energy Use Characterization**
 - To develop energy consumption estimates for the lamp or lamp-and-ballast systems selected in the engineering analysis.

- **Life-Cycle Cost and Payback Period Analyses**
 - To develop the customer life-cycle cost savings and payback period for higher efficiency lamps.

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Energy Use Characterization

Energy Use Characterization

- **Energy Use = Operating Hours x Power**
- **Distribution of Operating Hours developed by**
 - Lamp type (i.e., GSFL, IRL)
 - Sector (i.e., Residential, Commercial, Industrial)
 - Building type
 - Region (9 census divisions, 4 large states)
- **Power Developed in Engineering Analysis**
 - For IRL: lamp wattage
 - For GSFL: system power: depends on ballast factor and lamp wattage

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Energy Use Characterization

Residential Sector Operating Hours

- **2002 U.S. Lighting Market Characterization Vol I.:**
 - Average operating hours by building type (e.g., mobile home, single family detached, single family attached) and lamp type (i.e., IRL).
- **2001 Residential Energy Consumption Survey**
 - Probability a certain building type resides in one of nine census divisions and four large states.
- **Operating Hours of Average IRL: 884 hrs/year**
- **Sensitivity using high and low operating hours by room type:**
 - 1,210 hrs/ year (i.e., lamp placed in kitchen of a single-family detached)
 - 183 hrs/ year (i.e., lamp placed in the closet of a multi-family 2-4 unit)

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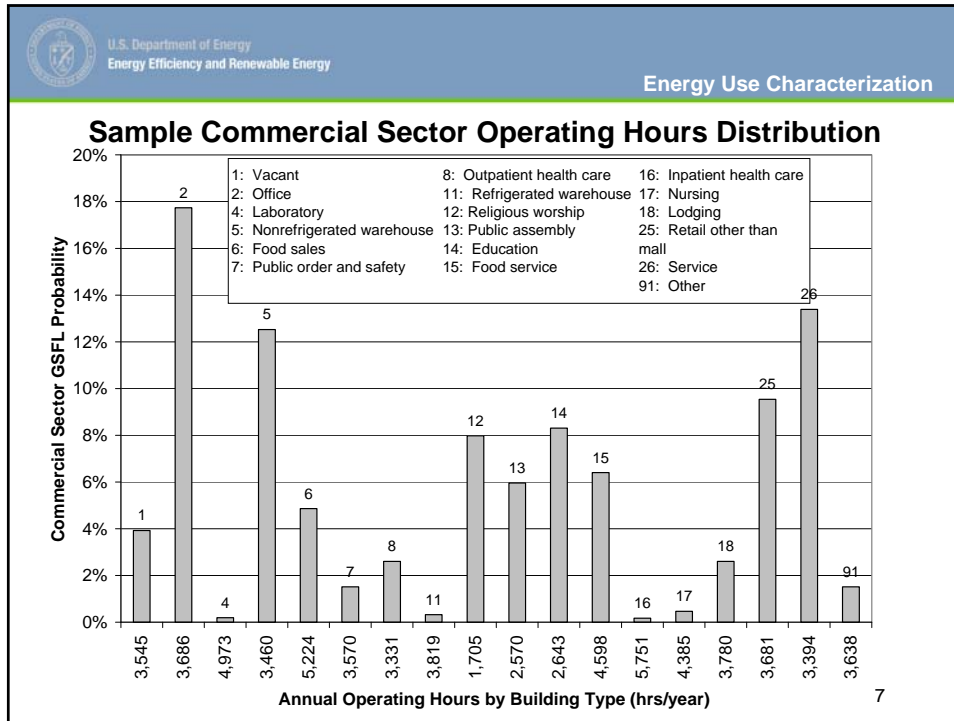
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Energy Use Characterization

Commercial Sector Operating Hours

- **2002 U.S. Lighting Market Characterization Vol I.:**
 - Average operating hours by building type (e.g., office, refrigerated warehouse, lodging, food sales) and lamp type (e.g., IRL, GSFL)
- **2003 Commercial Building Energy Consumption Survey**
 - Probability a certain building type resides in one of nine census divisions and four large states.
- **Operating Hours of Average IRL: 3,450 hrs/year**
- **Operating Hours of Average GSFL: 3,435 hrs/year**

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Energy Use Characterization

Industrial Sector Operating Hours

- **2002 U.S. Lighting Market Characterization Vol I.:**
 - Average operating hours by building type (e.g., printing and publishing, textile mill, fabricated metal products) and lamp type (e.g., IRL, GSFL)
- **2002 Manufacturer Energy Consumption Survey**
 - Probability a certain building type resides in the country
- **2007 Census**
 - Probability a certain building type resides in census division or large state
- **Operating Hours of Average IRL: 4,664 hrs/year**
- **Operating Hours of Average GSFL: 4,795 hrs/year**

DOE requests feedback on whether the average operating hours derived are a reasonable estimation of their end-uses. (Issue #6)

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Energy Use Characterization

Fluorescent System Power Rating

- DOE calculated system power rating using published catalog data.
- To estimate system power for a range of ballast factors with similar attributes (BEF, THD, etc.), DOE developed a linear fit.
- Example: 3-lamp 32W 4-foot T8 120V Ballasts with THD <20%, PF>0.95, and BEF 0.98 - 1.02

Ballast Factor	System Power Rating (W)
0.75	75.0
0.85	85.0
0.88	88.0
0.90	90.0
0.95	93.0
0.98	96.0

DOE invites comments on the system power rating of the lamp-and-ballast systems analyzed. (Issue #7)

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Life-Cycle Cost and Payback Period Analyses

Life-Cycle Cost and Payback Period Analyses

- Purpose: To develop the customer life-cycle cost (LCC) savings and payback period (PBP) for higher efficiency product compared to the baseline product.

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Life-Cycle Cost and Payback Period Analyses

Method

- LCC equals consumer price plus the sum of operating costs discounted to a particular base year.
- Economic evaluation from the consumer perspective.
- Analysis implemented in an Excel® spreadsheet.
- Results are expressed as LCC savings (baseline minus candidate efficiency level).
- Simple Payback Period (PBP, years) is also calculated and reported in this analysis.

```
graph TD; A["First Cost  
(Consumer Price +  
Installation Cost)"] --> C["Combine Changes  
in Costs"]; B["Operating  
Expenses"] --> C; D["Convert to Present Value"] --> C; C --> E["LCC Results"]
```

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Life-Cycle Cost and Payback Period Analyses

Approach

- The analysis only considers consumer choices that save energy:
 - Reduced-wattage lamps
 - Lamp and ballast combinations that have reduced system power
- Various events that trigger the purchasing of a lamp are considered.
- Varying lifetimes among lamp designs requires the use of a residual value.
- Distributions are correlated in analysis (e.g., operating hours, sales tax, and electricity prices are correlated by region).

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Life-Cycle Cost and Payback Period Analyses

Events Triggering the Purchase of Lamp

- Various events that trigger the purchasing of a lamp involve different consumer economics. DOE analyzes five such events:

IRL GSFL

- Lamp Failure - a lamp fails and must be replaced.
- Standards-Induced Retrofit - an increase in the efficacy standard prompts end-users to retrofit lamps and ballasts where, in the base case, they would otherwise only replace the lamp.
- Ballast Failure - an existing ballast fails and the consumer purchases a new lamp and ballast.
- Ballast Retrofit – consumers who were going to voluntarily retrofit their existing lamp and ballasts do so, and at certain CSLs are impacted by being forced to a higher standard.
- New Construction and Renovation - all the new fixture installations where the lighting design will be new or can be completely reconfigured.

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Life-Cycle Cost and Payback Period Analyses

Detailed Summary of Triggering Events for T12 Baseline Lamps

Event	Base Case Action	Standards Case Action
Lamp Failure	(a) Installs a T12 lamp.	Installs a lower-wattage, higher efficacy lamp, where the system light output never drops below 10 percent of the baseline system.
	(b) Installs a T12 lamp.	
Standards-Induced Retrofit	Replace T12 lamp halfway through analysis period.	Installs a T12 or T8 electronic ballast and lamp, where the system light output never drops below 10 percent of the baseline system.
Ballast Failure	Installs a T12 electronic ballast and lamps in the existing fixture.	
Ballast Retrofit	Installs a T8 electronic ballast and lamps in the existing fixture.	
New Construction and Renovation	Installs a new T12 system (only applies to T12 HO systems)	Installs a new T12 or T8 system that is where the system light output never drops below 10 percent of the baseline system. Light output can be maintained through spacing.

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Life-Cycle Cost and Payback Period Analyses

Detailed Summary of Triggering Events for T8 Baseline Lamps

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

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Life-Cycle Cost and Payback Period Analyses

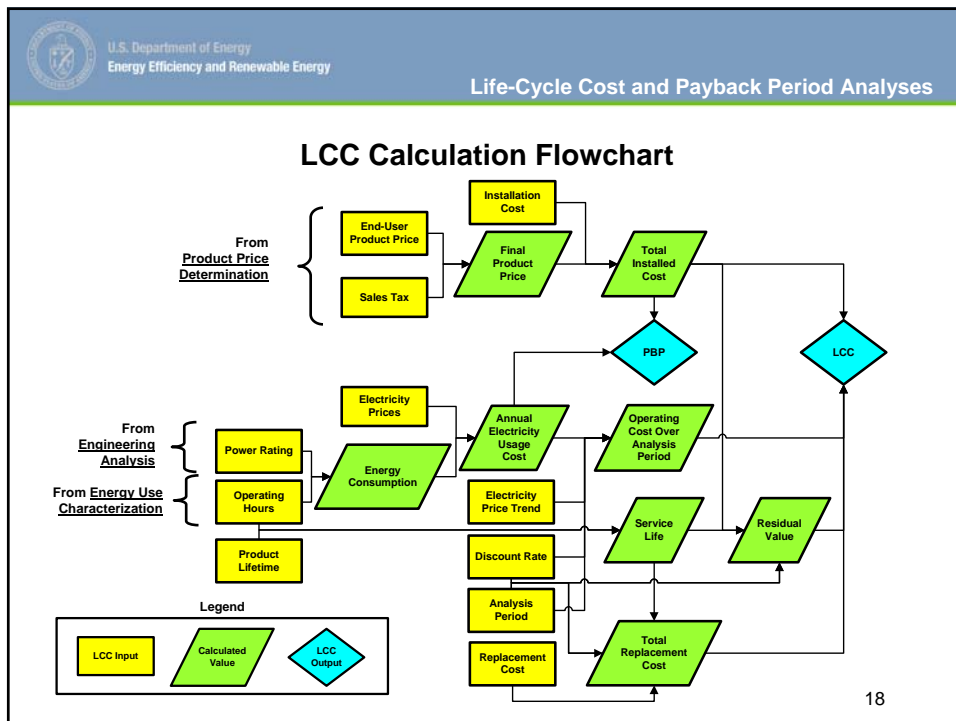
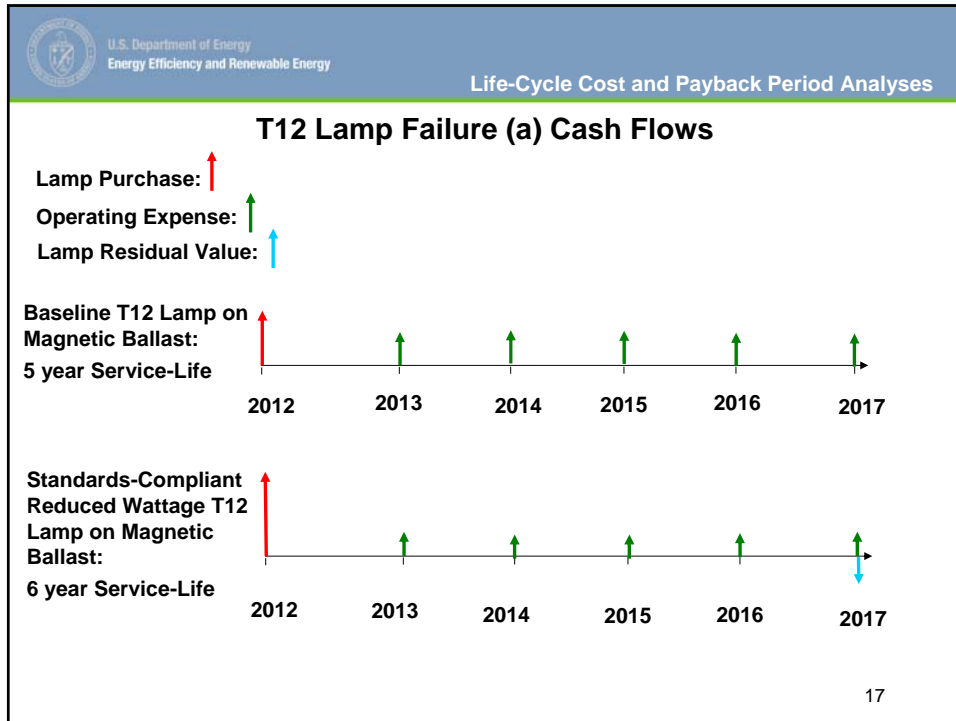
Residual Value


- To compare the life-cycle cost of two products, one must evaluate them over the same period of time (i.e., analysis period).
- The analysis period must be based on the lifetime of the product being regulated.
- To account for varying lifetimes among lamp designs, DOE uses a residual value (prorating the value of the remaining life of the lamp or ballast).
- The residual value is an estimate of the product's value to the consumer at the end of the life-cycle cost analysis period.

LCC = Installed Cost + Operating Cost – Residual Value

DOE seeks comment on the use of residual value and on other possible approaches to calculating life-cycle costs for products with varying lifetimes. (Issue #8)

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Life-Cycle Cost and Payback Period Analyses

Total Installed Costs

- **Total Installed Costs = Retail Price + Installation Cost**
- **Equipment Retail Price = End-User Product Price + Sales Tax**
 - End-User Product Price and Sales Tax developed in the *Product Price Determination*.
- **Installation costs represent the labor necessary to install the lamp or ballast.**
 - Labor Times (minutes):
 - GSFL: 2000 Ballast Rule (depends on lamp type, weighted average group and spot)
 - IRL: 2007 RS Means Electrical Cost Data. (DOE assumes no installation costs for IRL in the residential sector.)
 - Labor Rate (\$/hr):
 - Lamp Replacement: U.S. Bureau of Labor Statistics- General Maintenance Worker (\$15.49/hr)
 - Lamp and Ballast Replacement: 2007 RS Means-Electrician and Electrician's Helper (\$53.88/hr)

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Life-Cycle Cost and Payback Period Analyses

Installation Costs and the 2005 National Electric Code

- **The 2005 National Electric Code requires a means for disconnecting luminaires installed indoors.**
- **This new requirement may affect the labor time to install a fluorescent lamp ballast.**

DOE seeks comment on average labor times and labor rates. Specifically, DOE requests comment on how labor times will be affected by the 2005 National Electric Code. (Issue #9)

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Life-Cycle Cost and Payback Period Analyses

Electricity Prices

- **Electricity Prices**
 - Based on EIA Form 861 Data
 - Developed for 13 regions: 9 census divisions and 4 large states.

Geographic Area	Res. Elec (2006\$ / kWh)	Comm. Elec (2006\$ / kWh)	Ind. Elec (2006\$ / kWh)
New England	\$0.129	\$0.105	\$0.094
Middle Atlantic (excludes NY)	\$0.110	\$0.088	\$0.059
East North Central	\$0.087	\$0.075	\$0.054
West North Central	\$0.082	\$0.070	\$0.075
South Atlantic (excludes FL)	\$0.086	\$0.074	\$0.054
East South Central	\$0.078	\$0.078	\$0.065
West South Central (excludes TX)	\$0.086	\$0.079	\$0.065
Mountain	\$0.089	\$0.080	\$0.058
Pacific (excludes CA)	\$0.086	\$0.084	\$0.050
New York State	\$0.160	\$0.097	\$0.056
California	\$0.099	\$0.087	\$0.078
Texas	\$0.113	\$0.106	\$0.095
Florida	\$0.129	\$0.121	\$0.090
Weighted Average Prices	\$0.100	\$0.086	\$0.070

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Life-Cycle Cost and Payback Period Analyses

Electricity Price Trends

- **Electricity Price Trend**
 - Energy price projections to 2030 based on EIA/AEO Reference Case
 - AEO High Growth and Low Growth cases can be run as a sensitivity

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Life-Cycle Cost and Payback Period Analyses

Discount Rates

- **Based on the finance cost of raising funds to purchase products**
 - Financial cost of any debt incurred to purchase product
 - Opportunity cost of any equity used to purchase product
- **Residential Rates**
 - Weighted-average real rate associated with various household equity (e.g., savings bonds, stocks, CDs) and debt (e.g., credit card, home equity loans)
 - Primary data source: Federal Reserve Board's *Survey of Consumer Finances* for the years 1989, 1992, 1995, 1998, 2001, and 2004
 - Average Residential Discount Rate: **5.6%**
- **Commercial and Industrial Rates**
 - Calculated from the weighted-average cost of capital to the firm (WACC) to obtain equity and debt financing.
 - Cost of Equity calculated using the Capital Asset Pricing Model.
 - Cost of Debt calculated by adding a risk adjustment factor to the current yield on long-term corporate bonds.
 - Average Commercial Discount Rate: **6.2%**
 - Average Industrial Discount Rate: **7.5%**

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Life-Cycle Cost and Payback Period Analyses

Other Inputs

- **Lamp Lifetime:**
 - GSFL:
 - Manufacturing Literature: rated life for a 3-hr start
 - 2000 Ballast Rule: group and spot re-lamping rates (group replacements are made at 75% of rated life)
 - IRL: Manufacturing literature
- **Ballast Lifetime**
 - 2000 Ballast Rule: 49,054 hrs
- **Repair and Maintenance Costs**
 - No repair or maintenance costs are included
 - DOE does account for lamp replacements
- **Analysis Period**
 - Time span over which life-cycle cost is calculated
 - Based on the longest-lived baseline lamp in a product class.
 - The analysis period in years is equal to the life of the lamp in hours divided by the annual operating hours of the lamp for a given sector or building.

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Life-Cycle Cost and Payback Period Analyses

**3-lamp 4-foot Medium Bipin 34W T12 Baseline
Standards-Induced Retrofit LCC and PBP Results**

CSL	Lamp Efficacy <i>lm/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings \$	Payback Period <i>yr</i>	Mean Lumen From Baseline %
Baseline	77.9	34 W T12 & 0.88 BF Mag	138.35	N/A	11.04	N/A	N/A	0.0
CSL1	82.4	34 W T12 & 0.88 BF Elec	156.35	-18.00	65.93	4.44	12.4	7.0
CSL2	85.3	34 W T12 & 0.86 BF Elec	161.71	-23.36	72.96	4.81	12.9	10.9
CSL2	86.2	32.5 W T8 & 0.88 BF Elec	144.65	-6.31	56.52	5.56	8.2	9.6
CSL3	90.8	32.5 W T8 & 0.78 BF Elec	136.74	1.60	59.62	8.00	6.1	4.4
CSL3	91.2	34 W T12 & 0.86 BF Elec	162.00	-23.66	76.15	4.81	13.5	18.5
CSL4	92.3	32.5 W T8 & 0.75 BF Elec	132.09	6.26	60.05	8.73	5.6	5.6
CSL4	95.0	30 W T8 & 0.78 BF Elec	133.34	5.01	60.90	9.67	5.2	3.3
CSL5	95.4	32.5 W T8 & 0.75 BF Elec	133.47	4.88	61.61	8.73	5.8	8.0
CSL5	97.3	28 W T8 & 0.78 BF Elec	121.38	16.96	60.30	12.16	4.1	-1.3
CSL5	96.0	25 W T8 & 0.88 BF Elec	125.13	13.22	64.66	11.18	4.8	-0.9

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Life-Cycle Cost and Payback Period Analyses

**3-lamp 4-foot Medium Bipin 34W T12 Baseline
Ballast Failure LCC and PBP Results**

CSL	Lamp Efficacy <i>lm/W</i>	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings \$	Payback Period <i>yr</i>	Mean Lumen From Baseline %
Baseline	77.9	34 W T12 & 0.88 BF Elec	152.66	N/A	62.25	N/A	N/A	0.0
CSL1	82.4	34 W T12 & 0.86 BF Elec	154.69	-2.02	65.93	0.37	10.0	4.5
CSL2	85.3	34 W T12 & 0.86 BF Elec	161.71	-9.05	72.96	0.37	29.0	10.9
CSL2	86.2	32.5 W T8 & 0.88 BF Elec	144.65	8.01	56.52	1.12	0.0	9.6
CSL3	90.8	32.5 W T8 & 0.78 BF Elec	136.74	15.92	59.62	3.56	0.0	4.4
CSL3	91.2	34 W T12 & 0.86 BF Elec	162.00	-9.34	76.15	0.37	37.7	18.5
CSL4	92.3	32.5 W T8 & 0.75 BF Elec	132.09	20.58	60.05	4.29	0.0	5.6
CSL4	95.0	30 W T8 & 0.78 BF Elec	133.34	19.33	60.90	5.22	0.0	3.3
CSL5	95.4	32.5 W T8 & 0.75 BF Elec	133.47	19.19	61.61	4.29	0.0	8.0
CSL5	97.3	28 W T8 & 0.78 BF Elec	121.38	31.28	60.30	7.72	0.0	-1.3
CSL5	96.0	25 W T8 & 0.88 BF Elec	125.13	27.53	64.66	6.74	0.4	-0.9

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Life-Cycle Cost and Payback Period Analyses

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

CSL	Lamp Efficacy lm/W	Design Option	LCC \$	LCC Savings \$	Installed Price \$	Operating Cost Savings \$	Payback Period yr	Initial Lumens From Baseline %
Baseline	14.0	75W, 14 lm/W & 2,500 hrs, Halogen	25.53	N/A	6.16	N/A	N/A	0.0
CSL1	15.9	66W, 15.9 lm/W & 3,000 hrs, Improved Halogen	22.81	2.71	7.55	2.21	0.6	0.0
CSL2	17.5	60W, 17.5 lm/W & 3,000hrs, HIR	21.60	3.92	7.73	3.68	0.4	0.0
CSL3	19.1	55W, 19.1 lm/W & 4,000 hrs, Improved HIR	19.64	5.89	9.05	4.91	0.6	0.0

■ **Additional GSFL and IRL results can be found in Chapter 8 of the Technical Support Document.**

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Life-Cycle Cost and Payback Period Analyses

Life-Cycle Cost Sensitivities


■ **Sensitivity Results Shown in Appendix 8B of the Technical Support Document.**

- Monte Carlo Runs: variability in operating hours, sales tax, electricity prices, discount rates.
- High and Low Lamp Prices
- IRL: High and Low Operating Hours in Residential Sector
- GSFL: Assume No Ballast Price

■ **Other Possible Sensitivities**

- High and Low Growth Electricity Price Trends
- Variable Start Year
- Analysis Period as Multiple of Baseline Service Life
- Vary Sector for each Lamp Type

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Life-Cycle Cost and Payback Period Analyses

Other Issues

DOE seeks comment on any other aspects related to the Life-Cycle Cost and Payback Period Analyses.

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ANOPR Issues for Public Comment

- **Operating Hours (Issue #6)**
- **General Service Fluorescent Lamp Energy Consumption (Issue #7)**
- **Life-Cycle Cost Calculation (Issue #8)**
- **Installation Costs (Issue #9)**

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