# CHAPTER 11. LIFE-CYCLE COST SUBGROUP ANALYSIS

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# CHAPTER 11. LIFE-CYCLE COST SUBGROUP ANALYSIS

## 11.1 INTRODUCTION

The life-cycle cost (LCC) subgroup analysis evaluates impacts on any identifiable groups of customers who may, because of their particular socio-economic characteristics, be disproportionately affected by any national energy-efficiency standard level. This chapter of the technical support document (TSD) describes how the Department performed its life-cycle cost consumer subgroup analysis for the distribution transformer energy-efficiency standard rulemaking.

The Department conducted this evaluation for the notice of proposed rulemaking (NOPR), in part, by analyzing the LCC and payback periods for those customers that fall into identified subgroups. For this rulemaking, the Department defined consumer subgroups in terms of retail utility ownership type. The specific consumer subgroups that the Department chose to examine are rural electric cooperatives and municipal utilities.

## 11.2 ANALYSIS APPROACH

As part of the regular LCC analysis, the Department built spreadsheet analysis tools that provide a consumer economic analysis for a nationally representative sample of utilities. The Department developed a simplified approach to perform the consumer subgroup calculations: It adjusted the national data distributions for key analysis inputs by an appropriate scaling factor to produce an approximation of the input data for the consumer subgroup analysis. To estimate the economic impacts for the consumer subgroups, the Department then re-calculated the LCC with the adjusted input distributions. The subgroups examined are both subsets of the entire national electric utility sample and, hence, the analysis was limited to liquid-immersed distribution transformers, represented by design lines 1–5. The Department did not include dry-type distribution transformers, represented by design lines 9–13, in the LCC subgroup analysis since electric utilities use few, if any, dry-type transformers.

### 11.2.1 Adjustment Factors for Analysis Inputs

The Department selected three key data inputs that it adjusted for the consumer subgroup analysis:

1. Cost of electricity
2. Transformer loading
3. Transformer selection A and B factors

The Department implemented these adjustment factors using an "LCC Subgroup" pull-down menu included as part of its LCC spreadsheet tool. Table 11.2.1 shows the adjustment factors for the national sample and the subgroups.

**Table 11.2.1 Consumer Subgroup Economic Adjustment Factors**

| Subgroup | Cost of Electricity | Transformer Loading | A and B Factors |
|---|---|---|---|
| National sample | 1.00 | 1.00 | 1.00 |
| Rural cooperatives | 0.98 | 0.75 | 0.90 |
| Municipal utilities | 0.93 | 1.20 | 1.00 |

### 11.2.2 How the Department Estimated the Adjustment Factors

This section describes how the Department estimated the three adjustment factors for each of the two selected consumer subgroups.

For the cost of electricity, the Department examined the distribution of average electricity revenues per kilowatt-hour (kWh) for all utilities using Energy Information Administration (EIA) Form 861 data for different ownership classes (privately owned, cooperatives, and municipal utilities).[1] For the purposes of this analysis, the Department assumed that the EIA ownership classification of "Political Subdivision" corresponded to a type of municipal utility. Its examination revealed that the distribution of unit revenues for different retail utility ownership classes is very similar. The Department then calculated the weighted-average unit revenues for the different ownership classes of retail utilities. It found that the average unit revenue for rural cooperatives is 98 percent of that for the national sample, and that average unit revenue for municipal utilities is 93 percent of that for the national sample.

For transformer loading estimates, the data available to the Department consisted of rough loading estimates mentioned in stakeholder comments. The Department's estimate of average root mean square (RMS) loading for a 50 kilovolt-ampere (kVA) pad-mounted transformer for the national sample is 35 percent. Stakeholders commented that rural cooperative transformers tend to have lower loadings because of oversizing to control for voltage flicker and lack of load diversity, while municipal utility transformers tend to have more diversity and, thus, higher loadings. The typical rural cooperative transformer will serve a single customer, while the typical urban transformer will serve multiple customers. Thus, the Department estimated an adjustment factor of 0.75 for rural cooperatives, and 1.20 for municipal utilities, which results in average RMS loading estimates of 26 percent and 42 percent for 50 kVA transformers for rural cooperatives and municipal utilities, respectively.

For customer evaluation A and B factors, the Department was given factors for rural cooperatives by the National Rural Electric Cooperative Association (NRECA) in stakeholder comments; it compiled data from public sources for municipal utilities. The Department found the evaluation parameters for rural cooperatives to be 10 percent lower than the national sample average and the parameters for municipal utilities to be approximately the same as the national sample average for the available data.

## 11.3 LIFE-CYCLE COST SUBGROUP RESULTS

This section presents the results of the LCC subgroup analysis for municipal utilities and rural electric cooperatives. The results for each subgroup and each design line are presented in tables that report the candidate standard level,[a] the percentage of transformers that have net savings, no impact, and net LCC cost (i.e., negative savings); and the mean LCC savings.

### 11.3.1 Municipal Utilities Subgroup Life-Cycle Cost Results

The LCC results for the municipal utilities subgroup are a reflection of a key feature of this subgroup: Transformers purchased by municipal utilities tend to serve more diverse, urban loads than transformers that serve more rural areas. The increased load diversity increases the load factor and the transformer loading, thus increasing the potential savings from reduced load losses. Because of the increased savings from reduced load losses, the LCC savings for the municipal utilities subgroup are slightly higher than for the national sample. The extra LCC savings vary as a function of both the design line and the standard level, since the relative importance of load losses varies with both design line and transformer efficiency.

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[a] In this chapter of the TSD, LCC results are described in terms of candidate standard levels (CSLs). In the NOPR itself, LCC results are described in terms of trial standard levels (TSLs). The TSLs are the efficiency levels used in post-LCC analyses and they are also used to describe the standard levels considered by the Department for the proposed standard. TSLs are based on the CSLs selected for the LCC. However, because of special considerations concerning manufacturer impacts and design lines (DLs) contained within the same product class, efficiency levels— and therefore CSLs—do not change for some standard level increments for DL1 and DL4. See TSD chapter 10 for a more detailed explanation. The table below shows the mapping from the design line CSLs to the TSLs. The analysis reported in this chapter and in the NOPR is the same, but is reported in slightly different formats in the two documents, according to this CSL-to-TSL mapping.

**Mapping of the Candidate Standard Levels to Trial Standard Levels**

| | DL1 | DL2 | DL3 | DL4 | DL5 | DL9 | DL10 | DL11 | DL12 | DL13 |
|---|---|---|---|---|---|---|---|---|---|---|
| **TSL1** | CSL1 | CSL1 | CSL1 | CSL1 | CSL1 | CSL1 | CSL1 | CSL1 | CSL1 | CSL1 |
| **TSL2** | CSL1 | CSL2 | CSL2 | CSL2 | CSL2 | CSL2 | CSL2 | CSL2 | CSL2 | CSL2 |
| **TSL3** | CSL1 | CSL3 | CSL3 | CSL3 | CSL3 | CSL3 | CSL3 | CSL3 | CSL3 | CSL3 |
| **TSL4** | CSL2 | CSL4 | CSL4 | CSL3 | CSL4 | CSL4 | CSL4 | CSL4 | CSL4 | CSL4 |
| **TSL5** | CSL3 | CSL5 | CSL5 | CSL5 | CSL5 | CSL5 | CSL5 | CSL5 | CSL5 | CSL5 |
| **TSL6** | CSL6 | CSL6 | CSL6 | CSL6 | CSL6 | CSL6 | CSL6 | CSL6 | CSL6 | CSL6 |

#### 11.3.1.1 Design Line 1 Life-Cycle Cost Results

Table 11.3.1 presents the summary of the LCC subgroup analysis for municipal utilities for the representative unit from design line 1, a 50 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that nearly 65 percent of the transformers are not impacted by candidate standard level (CSL) 1, while more than 95 percent of transformers are impacted by a CSL 4 standard level or higher. CSLs 3, 5, and 6 result in a majority of transformers experiencing a net cost due to a standard. With CSLs 1, 2, and 4, a majority of affected transformers experience a net savings. There is a net average LCC savings for CSLs 1 through 5, while there is a net average LCC cost for CSL 6. For CSLs 1 through 5, the net average LCC impact is less than 4 percent of the average baseline LCC of $4,842.

**Table 11.3.1 Municipal Utilities Subgroup Life-Cycle Cost Results: Design Line 1**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Efficiency (%) | 98.9 | 99.04 | 99.19 | 99.33 | 99.49 | 99.59 |
| Transformers having LCC Savings > $0 (%) | 30.60 | 34.34 | 36.22 | 65.04 | 41.88 | 12.65 |
| Transformers having LCC Savings = $0 (%) | 64.69 | 51.40 | 15.20 | 4.98 | 2.03 | 0.00 |
| Transformers having LCC Savings < $0 (%) | 4.71 | 14.26 | 48.58 | 29.98 | 56.09 | 87.35 |
| Mean LCC Savings ($) | 95 | 120 | 64 | 177 | 57 | -594 |

#### 11.3.1.2 Design Line 2 Life-Cycle Cost Results

Table 11.3.2 presents the summary of the LCC subgroup analysis for municipal utilities for the representative unit from design line 2, a 25 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that over 66 percent of the transformers are not impacted by CSL 1, while 75 percent or more of transformers are impacted by a CSL 5 standard level or higher. CSLs 5 and 6 result in a majority of transformers experiencing a net cost due to a standard. With CSLs 1 through 4, the majority of affected transformers experience a net savings. There is a net average LCC savings for CSLs 1 through 5, while there is a net average LCC cost for CSL 6. For CSLs 1 through 5, the net average LCC impact is less than 3 percent of the average baseline LCC of $3,025.

**Table 11.3.2 Municipal Utilities Subgroup Life-Cycle Cost Results: Design Line 2**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| Efficiency (%) | 98.7 | 98.73 | 98.76 | 98.79 | 98.96 | 99.46 |
| Transformers having LCC Savings > $0 (%) | 32.6 | 31.7 | 34.1 | 35.4 | 32.1 | 1.4 |
| Transformers having LCC Savings = $0 (%) | 66.1 | 65.3 | 60.7 | 55.9 | 25.1 | 0.0 |
| Transformers having LCC Savings < $0 (%) | 1.4 | 3.0 | 5.2 | 8.7 | 42.8 | 98.6 |
| Mean LCC Savings ($) | 69 | 66 | 70 | 73 | 17 | -926 |

### 11.3.1.3 Design Line 3 Life-Cycle Cost Results

Table 11.3.3 presents the summary of the LCC subgroup analysis for municipal utilities for the representative unit from design line 3, a 500 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that over 73 percent of the transformers are not impacted by CSL 1, while 96 percent or more of transformers are impacted by a CSL 4 standard level or higher. CSLs 5 and 6 result in a majority of transformers experiencing a net cost due to a standard. With CSLs 1 through 4, a majority of affected transformers experience a net savings. There is a net average LCC savings for all levels. For CSLs 2 through 4, the net average LCC savings are greater than 10 percent of the average baseline LCC of $25,200.

**Table 11.3.3 Municipal Utilities Subgroup Life-Cycle Cost Results: Design Line 3**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| Efficiency (%) | 99.3 | 99.38 | 99.46 | 99.54 | 99.74 | 99.75 |
| Transformers having LCC Savings > $0 (%) | 26.0 | 34.0 | 45.3 | 57.2 | 39.3 | 35.9 |
| Transformers having LCC Savings = $0 (%) | 73.9 | 64.8 | 49.6 | 4.0 | 0.1 | 0.0 |
| Transformers having LCC Savings < $0 (%) | 0.1 | 1.2 | 5.1 | 38.8 | 60.6 | 64.1 |
| Mean LCC Savings ($) | 2,109 | 2,765 | 3,607 | 3,693 | 1,745 | 1,102 |

### 11.3.1.4 Design Line 4 Life-Cycle Cost Results

Table 11.3.4 presents the summary of the LCC subgroup analysis for municipal utilities for the representative unit from design line 4, a 150 kVA, liquid-immersed, three-phase distribution transformer. For this unit, the Department forecasts that more than 64 percent of the transformers are not impacted by CSL 1, while more than 88 percent of transformers are impacted by a CSL 3 standard level or higher. CSL 3 has similar fractions of affected transformers with net savings and net costs, while CSLs 5 and 6 result in a majority of transformers experiencing a net cost due to a standard. With CSLs 1, 2, and 4, the majority of affected transformers obtain a net savings from a standard. There is a net average LCC savings for CSLs 1 through 5, while there is a net average LCC cost for CSL 6. For CSLs 1 through 6, the net average LCC impact is less than 8 percent of the average baseline LCC of $12,501.

**Table 11.3.4 Municipal Utilities Subgroup Life-Cycle Cost Results: Design Line 4**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Efficiency (%) | 98.9 | 99.08 | 99.26 | 99.45 | 99.58 | 99.61 |
| Transformers having LCC Savings > $0 (%) | 32.9 | 45.9 | 46.4 | 57.6 | 41.6 | 30.7 |
| Transformers having LCC Savings = $0 (%) | 64.1 | 39.8 | 11.7 | 9.8 | 0.8 | 0.0 |
| Transformers having LCC Savings < $0 (%) | 3.0 | 14.4 | 41.9 | 32.6 | 57.7 | 69.3 |
| Mean LCC Savings ($) | 608 | 808 | 512 | 905 | 435 | -165 |

#### 11.3.1.5 Design Line 5 Life-Cycle Cost Results

Table 11.3.5 presents the summary of the LCC subgroup analysis for municipal utilities for the representative unit from design line 5, a 1500 kVA, liquid-immersed, three-phase distribution transformer. For this unit, the Department forecasts that 72 percent of the transformers are not impacted by CSL 1, while more than 75 percent of transformers are impacted by a CSL 5 standard level or higher. CSLs 5 and 6 have approximately equal proportions of transformers incurring a net cost and a net savings as a result of a standard, and CSLs 1 through 4 result in the majority of affected transformers obtaining a net savings from a standard. There is a net average LCC savings for all CSLs. For CSLs 3 through 6, the net average LCC savings are more than 10 percent of the average baseline LCC of $71,738.

**Table 11.3.5 Municipal Utilities Subgroup Life-Cycle Cost Results: Design Line 5**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| Efficiency (%) | 99.3 | 99.36 | 99.42 | 99.47 | 99.71 | 99.71 |
| Transformers having LCC Savings > $0 (%) | 27.6 | 34.8 | 50.4 | 61.4 | 50.1 | 49.9 |
| Transformers having LCC Savings = $0 (%) | 72.1 | 64.0 | 40.9 | 24.4 | 0.1 | 0.1 |
| Transformers having LCC Savings < $0 (%) | 0.3 | 1.2 | 8.8 | 14.1 | 49.8 | 50.0 |
| Mean LCC Savings ($) | 4,853 | 6,649 | 8,128 | 9,013 | 7,680 | 7,453 |

## 11.3.2 Rural Cooperatives Subgroup Life-Cycle Cost Results

The LCC results for the rural cooperatives subgroup are a reflection of a key feature of this subgroup: Distribution transformers purchased by rural cooperatives tend to serve smaller loads than transformers that serve urban areas. The lower loading decreases the potential savings from reduced load losses and, thus, the benefits from efficiency improvements. Because of the reduced savings from reduced load losses, the LCC savings for the rural cooperatives subgroup are slightly less than for the national sample. The diminished LCC savings vary as a function of both the design line and the standard level, since the relative importance of load losses varies with both design line and transformer efficiency. The LCC savings for rural cooperatives are also, on average, less than for the municipal utility case per affected transformer.

### 11.3.2.1 Design Line 1 Life-Cycle Cost Results

Table 11.3.6 presents the summary of the LCC subgroup analysis for rural cooperatives for the representative unit from design line 1, a 50 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that 64 percent of transformers are impacted by a CSL 1 standard level while 98 percent of transformers are impacted by a CSL 4 standard level. There is a net average LCC savings for CSLs 1, 2, and 4, while there is a net average LCC cost for CSLs 3, 5, and 6. For all standard levels except CSL 6, the net average LCC impact is less than 3 percent of the average baseline LCC of $4,431.

**Table 11.3.6 Rural Cooperatives Subgroup Life-Cycle Cost Results: Design Line 1**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Efficiency (%) | 98.9 | 99.04 | 99.19 | 99.33 | 99.49 | 99.59 |
| Transformers having LCC Savings > $0 (%) | 29.62 | 29.80 | 25.86 | 67.91 | 32.40 | 3.87 |
| Transformers having LCC Savings = $0 (%) | 64.38 | 50.23 | 11.28 | 2.04 | 1.03 | 0.00 |
| Transformers having LCC Savings < $0 (%) | 6.00 | 19.97 | 62.86 | 30.05 | 66.57 | 96.13 |
| Mean LCC Savings ($) | 79 | 58 | -91 | 146 | -106 | -861 |

### 11.3.2.2 Design Line 2 Life-Cycle Cost Results

Table 11.3.7 presents the summary of the LCC subgroup analysis for rural cooperatives for the representative unit from design line 2, a 25 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that 64 percent of rural cooperative transformers are not impacted by a CSL 1 standard level while more than 80 percent of transformers are impacted by a CSL 5 standard level or higher. Transformers that incur a net LCC cost resulting from a standard dominate the affected transformers for CSLs 5 and 6, while CSLs 1 through 4 have more affected transformers with net savings. There are net average LCC savings for CSLs 1 through 4, while there is a net average LCC cost for CSLs 5 and 6. For all standard levels except CSL 6, the net average LCC impact is less than 3 percent of the average baseline LCC of $2,849.

**Table 11.3.7 Rural Cooperatives Subgroup Life-Cycle Cost Results: Design Line 2**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Efficiency (%) | 98.7 | 98.73 | 98.76 | 98.79 | 98.96 | 99.46 |
| Transformers having LCC Savings > $0 (%) | 33.7 | 33.9 | 35.7 | 36.2 | 27.8 | 0.4 |
| Transformers having LCC Savings = $0 (%) | 64.4 | 62.0 | 57.2 | 51.9 | 18.9 | 0.0 |
| Transformers having LCC Savings < $0 (%) | 1.9 | 4.1 | 7.2 | 11.9 | 53.3 | 99.6 |
| Mean LCC Savings ($) | 69 | 66 | 67 | 63 | -25 | -1,040 |

#### 11.3.2.3 Design Line 3 Life-Cycle Cost Results

Table 11.3.8 presents the summary of the LCC subgroup analysis for rural cooperatives for the representative unit from design line 3, a 500 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that 72 percent of transformers are not impacted by CSL 1, while more than 97 percent of transformers are impacted by a CSL 4 standard level or higher. CSLs 5 and 6 result in a majority of transformers with a net cost as a result of a standard, and CSLs 1 through 3 have the majority of affected transformers incurring a net savings. CSL 4 has approximately equal numbers of affected transformers with net costs and net savings. There are net average LCC savings for CSLs 1 through 4, while there is a net average LCC cost for CSLs 5 and 6. For CSLs 1 through 5, the net average LCC impact is less than 10 percent of the average baseline LCC of $19,109.

**Table 11.3.8 Rural Cooperatives Subgroup Life-Cycle Cost Results: Design Line 3**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Efficiency (%) | 99.3 | 99.38 | 99.46 | 99.54 | 99.74 | 99.75 |
| Transformers having LCC Savings > $0 (%) | 27.5 | 33.0 | 41.0 | 49.5 | 21.7 | 17.6 |
| Transformers having LCC Savings = $0 (%) | 72.4 | 64.9 | 49.4 | 2.3 | 0.1 | 0.0 |
| Transformers having LCC Savings < $0 (%) | 0.1 | 2.2 | 9.6 | 48.3 | 78.3 | 82.4 |
| Mean LCC Savings ($) | 1,288 | 1,525 | 1,669 | 1,579 | -1,630 | -2,573 |

#### 11.3.2.4 Design Line 4 Life-Cycle Cost Results

Table 11.3.9 presents the summary of the LCC subgroup analysis for rural cooperatives for the representative unit from design line 4, a 150 kVA, liquid-immersed, three-phase distribution transformer. For this unit, the Department forecasts that 63 percent of the transformers are not impacted by CSL 1, while more than 93 percent of transformers are impacted by a CSL 3 standard level or higher. CSLs 3, 5, and 6 result in a majority of transformers experiencing a net cost as a result of a standard. CSLs 1, 2, and 4 have the majority of affected transformers obtaining a net savings from a standard. There is a net average LCC savings for CSLs 1 through 4, while there is a net average LCC cost for CSLs 5 and 6. For CSLs 1 through 5, the net average LCC impact is less than 5 percent of the average baseline LCC of $10,718.

**Table 11.3.9 Rural Cooperatives Subgroup Life-Cycle Cost Results: Design Line 4**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Efficiency (%) | 98.9 | 99.08 | 99.26 | 99.45 | 99.58 | 99.61 |
| Transformers having LCC Savings > $0 (%) | 31.7 | 38.6 | 43.7 | 56.1 | 22.5 | 14.6 |
| Transformers having LCC Savings = $0 (%) | 63.1 | 38.5 | 5.7 | 6.1 | 0.6 | 0.0 |
| Transformers having LCC Savings < $0 (%) | 5.2 | 22.9 | 50.6 | 37.8 | 76.9 | 85.4 |
| Mean LCC Savings ($) | 412 | 370 | 183 | 448 | -599 | -1,320 |

### 11.3.2.5 Design Line 5 Life-Cycle Cost Results

Table 11.3.10 presents the summary of the LCC subgroup analysis for rural cooperatives for the representative unit from design line 5, a 1500 kVA, liquid-immersed, three-phase distribution transformer. For this unit, the Department forecasts that nearly 71 percent of the transformers are not impacted by CSL 1, while more than 79 percent of transformers are impacted by a CSL 4 standard level or higher. CSLs 5 and 6 result in a majority of transformers incurring a net cost, and CSLs 1 through 4 have the majority of affected transformers incurring a net savings from a standard. There are net average LCC savings for CSLs 1 through 4. For all CSLs, the net average LCC impact is less than 8 percent of the average baseline LCC of $49,040.

**Table 11.3.10 Rural Cooperatives Subgroup Life-Cycle Cost Results: Design Line 5**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Efficiency (%) | 99.3 | 99.36 | 99.42 | 99.47 | 99.71 | 99.71 |
| Transformers having LCC Savings > $0 (%) | 28.2 | 34.6 | 43.1 | 51.7 | 21.9 | 21.2 |
| Transformers having LCC Savings = $0 (%) | 70.9 | 62.4 | 39.6 | 20.8 | 0.1 | 0.0 |
| Transformers having LCC Savings < $0 (%) | 0.9 | 3.1 | 17.4 | 27.5 | 78.0 | 78.8 |
| Mean LCC Savings ($) | 2,243 | 3,013 | 3,084 | 3,239 | -3,617 | -3,775 |

## 11.4 PAYBACK PERIOD RESULTS

As described in more detail in section 8.6, a common technique for evaluating investment decisions is to perform a payback period (PBP) analysis. A more energy-efficient device will usually cost more to purchase than a device of standard energy efficiency, while the more efficient device will usually cost less to operate. Operating expenses decrease due to a reduction in energy use. The payback period is the time (usually expressed in years) it takes to recover the additional first cost of the efficiency device with its energy cost savings. Because the Department analyzed the economics of a nationally representative distribution of transformers, DOE provides results in terms of a distribution of payback periods.

There are several potential complications to performing an analysis of a distribution of PBP estimates (see section 8.6). Specifically, a payback period is a ratio of increased first cost and decreased operating expenses. When there is a distribution of changes for both first cost and operating expense reductions, the average of the ratio does not equal the ratio of the averages. Therefore, in the tables below, the Department reports all quantities of interest: the mean PBP, the mean incremental first cost, and the average decrease in annual operating expenses (in the first year of operation). These quantities allow stakeholders to compare the average PBP to a ratio of the mean incremental first cost increase and the mean operating cost savings. These two values are comparable, but not equal, because not all transformer purchase decision computations have well-defined PBPs.

### 11.4.1 Municipal Utilities Subgroup Payback Period Results

The PBP results for the municipal utilities subgroup are a reflection of a key feature of this subgroup. This key feature is that distribution transformers purchased by municipal utilities tend to serve more diverse, urban loads than transformers that serve more rural areas. The increased load diversity increases the load factor and the transformer loading, thus increasing the potential savings from reduced load losses. While the mean PBP for the municipal utilities subgroup is generally shorter than the PBP for the national sample, it is often within a year of the national sample mean PBP. Compared to the rural cooperatives subgroup, the benefits from efficiency improvements are on average greater for municipal utilities, and the PBP tends to be slightly smaller than that for rural cooperatives.

#### 11.4.1.1 Design Line 1 Payback Period Results

Table 11.4.1 presents the summary of the PBP subgroup analysis for municipal utilities for the representative unit from design line 1, a 50 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that nearly 65 percent of the transformers are not impacted by CSL 1, while nearly 95 percent or more of transformers are impacted by a CSL 4 standard level or higher. Undefined[a] PBPs remain below three percent for all CSLs. Mean distribution PBPs for this design line range from 11 to 43 years; CSL 1 has the minimum distribution PBP.

**Table 11.4.1 Municipal Utilities Subgroup Payback Period Results: Design Line 1**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| Mean Payback (Years) | 11.1 | 19.9 | 33.2 | 16.0 | 23.8 | 43.0 |
| Transformers Not Impacted by Standard (%) | 64.7 | 51.4 | 15.2 | 5.0 | 2.0 | 0.0 |
| Transformers having Well-Defined Payback (%) | 34.7 | 47.5 | 82.1 | 94.6 | 97.9 | 99.7 |
| Transformers having Undefined Payback (%) | 0.7 | 1.1 | 2.7 | 0.4 | 0.1 | 0.3 |
| Mean Incremental First Cost ($) | 165 | 312 | 492 | 508 | 879 | 1678 |
| Mean Operating Cost Savings ($) | 22 | 26 | 25 | 35 | 44 | 50 |

### 11.4.1.2 Design Line 2 Payback Period Results

Table 11.4.2 presents the summary of the PBP subgroup analysis for municipal utilities for the representative unit from design line 2, a 25 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that 66 percent of transformers are not impacted by CSL 1, while 72 percent or more of transformers are impacted by a CSL 5 standard level or higher. Undefined PBPs are five percent or less for all CSLs. Mean PBPs for this design line range from 5 to 65 years, with a monotonic (i.e., never reversing direction) increase in mean PBP with increasing CSL.

[a] Undefined refers to all invalid PBP computations. See section 8.6 for a full discussion.

**Table 11.4.2 Municipal Utilities Subgroup Payback Period Results: Design Line 2**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Mean Payback (Years) | 4.8 | 7.0 | 8.8 | 12.0 | 30.6 | 65.4 |
| Transformers Not Impacted by Standard (%) | 66.1 | 65.3 | 60.7 | 55.9 | 25.1 | 0.0 |
| Transformers having Well-Defined Payback (%) | 29.0 | 33.5 | 37.4 | 41.9 | 72.2 | 100.0 |
| Transformers having Undefined Payback (%) | 5.0 | 1.2 | 1.8 | 2.2 | 2.7 | 0.0 |
| Mean Incremental First Cost ($) | 32 | 49 | 59 | 76 | 241 | 1,472 |
| Mean Operating Cost Savings ($) | 12 | 12 | 12 | 12 | 13 | 26 |

#### 11.4.1.3 Design Line 3 Payback Period Results

Table 11.4.3 presents the summary of the PBP subgroup analysis for municipal utilities for the representative unit from design line 3, a 500 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that over 73 percent of the transformers are not impacted by CSL 1, while 93 percent of transformers are impacted by a CSL 4 standard level or higher. Undefined PBPs remain below 11 percent for all CSLs. For this design line, PBPs increase monotonically from 1 to 30 years with increasing CSL.

**Table 11.4.3 Municipal Utilities Subgroup Payback Period Results: Design Line 3**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Mean Payback (Years) | 1.2 | 3.8 | 8.7 | 19.2 | 27.4 | 29.9 |
| Transformers Not Impacted by Standard (%) | 73.9 | 64.8 | 49.6 | 4.0 | 0.1 | 0.0 |
| Transformers having Well-Defined Payback (%) | 16.0 | 34.9 | 50.1 | 93.0 | 99.8 | 100.0 |
| Transformers having Undefined Payback (%) | 10.1 | 0.3 | 0.3 | 3.0 | 0.0 | 0.0 |
| Mean Incremental First Cost ($) | 125 | 622 | 1,315 | 1,862 | 8,260 | 9,356 |
| Mean Operating Cost Savings ($) | 345 | 360 | 352 | 243 | 439 | 455 |

#### 11.4.1.4 Design Line 4 Payback Period Results

Table 11.4.4 presents the summary of the PBP subgroup analysis for municipal utilities for the representative unit from design line 4, a 150 kVA, liquid-immersed, three-phase distribution transformer. For this unit, the Department forecasts that more than 64 percent of the transformers are not impacted by CSL 1, while more than 88 percent of transformers are impacted by a CSL 3 standard level or higher. For this design line, transformers with undefined PBPs are 1 percent or fewer of all transformers. Mean distribution PBP ranges from 8 to 30 years, with a dip in mean PBP for CSL 4.

**Table 11.4.4 Municipal Utilities Subgroup Payback Period Results: Design Line 4**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Mean Payback (Years) | 7.7 | 15.0 | 21.5 | 16.9 | 27.1 | 32.5 |
| Transformers Not Impacted by Standard (%) | 64.1 | 39.8 | 11.7 | 9.8 | 0.8 | 0.0 |
| Transformers having Well-Defined Payback (%) | 34.8 | 59.5 | 87.7 | 90.1 | 99.1 | 100.0 |
| Transformers having Undefined Payback (%) | 1.0 | 0.7 | 0.6 | 0.1 | 0.2 | 0.0 |
| Mean Incremental First Cost ($) | 480 | 902 | 1,542 | 1,951 | 3,341 | 4,193 |
| Mean Operating Cost Savings ($) | 99 | 99 | 104 | 142 | 172 | 181 |

### 11.4.1.5 Design Line 5 Payback Period Results

Table 11.4.5 presents the summary of the PBP subgroup analysis for municipal utilities for the representative unit from design line 5, a 1500 kVA, liquid-immersed, three-phase distribution transformer. For this unit, the Department forecasts that 72 percent of the transformers are not impacted by CSL 1, while 75 percent or more of transformers are impacted by a CSL 4 standard level or higher. Undefined PBPs remain below 2 percent of transformers for all CSLs. Mean distribution PBP ranges from 3 to 24 years and increases monotonically with increasing CSL.

**Table 11.4.5 Municipal Utilities Subgroup Payback Period Results: Design Line 5**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Mean Payback (Years) | 2.9 | 5.1 | 11.0 | 12.9 | 23.7 | 23.7 |
| Transformers Not Impacted by Standard (%) | 72.1 | 64.0 | 40.9 | 24.4 | 0.1 | 0.1 |
| Transformers having Well-Defined Payback (%) | 27.9 | 35.9 | 58.1 | 74.7 | 99.9 | 99.9 |
| Transformers having Undefined Payback (%) | 0.0 | 0.1 | 1.1 | 0.9 | 0.0 | 0.0 |
| Mean Incremental First Cost ($) | 1,468 | 2,552 | 3,041 | 4,430 | 19,660 | 19,607 |
| Mean Operating Cost Savings ($) | 759 | 855 | 683 | 685 | 1,183 | 1,168 |

## 11.4.2 Rural Cooperatives Subgroup Payback Period Results

The PBP results for the rural cooperatives subgroup are a reflection of a key feature of this subgroup: Distribution transformers purchased by rural cooperatives tend to serve smaller loads than transformers that serve urban areas. The lower loading decreases the potential savings from reduced load losses, and thus the benefits from efficiency improvements are on average less than the national average case per affected transformer, and payback times will be longer than the national average.

### 11.4.2.1 Design Line 1 Payback Period Results

Table 11.4.6 presents the summary of the LCC subgroup analysis for rural cooperatives for the representative unit from design line 1, a 50 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that nearly 65 percent of transformers are not impacted by a CSL 1 standard level, while 98 percent of transformers are impacted by a CSL 4 standard level. Undefined paybacks remain below three percent for all CSLs except CSL 3. CSL 1 has the minimum mean distribution PBP and CSL 4, at 16 years, also has relatively low PBP. The PBP ranges from 12 to 49 years over the range of CSLs.

**Table 11.4.6 Rural Cooperatives Subgroup Payback Period Results: Design Line 1**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| Mean Payback (Years) | 12.4 | 25.2 | 41.2 | 16.0 | 25.6 | 49.3 |
| Transformers Not Impacted by Standard (%) | 64.4 | 50.2 | 11.3 | 2.0 | 1.0 | 0.0 |
| Transformers having Well-Defined Payback (%) | 34.5 | 47.4 | 82.7 | 97.7 | 98.8 | 99.4 |
| Transformers having Undefined Payback (%) | 1.2 | 2.4 | 6.0 | 0.3 | 0.2 | 0.6 |
| Mean Incremental First Cost ($) | 164 | 312 | 486 | 508 | 879 | 1687 |
| Mean Operating Cost Savings ($) | 20 | 20 | 18 | 34 | 38 | 40 |

#### 11.4.2.2 Design Line 2 Payback Period Results

Table 11.4.7 presents the summary of the LCC subgroup analysis for rural cooperatives for the representative unit from design line 2, a 25 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that nearly 65 percent of rural cooperative transformers are not impacted by a CSL 1 standard level, while over 76 percent of transformers are impacted by a CSL 5 standard level or higher. Undefined PBPs remain below six percent for all CSLs. Mean PBPs for this design line range from 5 to 72 years, with a monotonic increase in mean PBP with increasing CSL.

**Table 11.4.7 Rural Cooperatives Subgroup Payback Period Results: Design Line 2**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| Mean Payback (Years) | 5.4 | 7.6 | 9.9 | 14.0 | 35.6 | 72.5 |
| Transformers Not Impacted by Standard (%) | 64.4 | 62.0 | 57.2 | 51.9 | 18.9 | 0.0 |
| Transformers having Well-Defined Payback (%) | 29.9 | 36.4 | 39.5 | 44.2 | 76.7 | 100.0 |
| Transformers having Undefined Payback (%) | 5.7 | 1.6 | 3.3 | 3.9 | 4.4 | 0.0 |
| Mean Incremental First Cost ($) | 31 | 48 | 58 | 75 | 243 | 1,496 |
| Mean Operating Cost Savings ($) | 12 | 12 | 11 | 10 | 11 | 23 |

#### 11.4.2.3 Design Line 3 Payback Period Results

Table 11.4.8 presents the summary of the LCC subgroup analysis for rural cooperatives for the representative unit from design line 3, a 500 kVA, liquid-immersed, single-phase distribution transformer. For this unit, the Department forecasts that nearly 73 percent of the transformers are not impacted by CSL 1, while more than 95 percent of transformers are impacted by a CSL 4 standard level or higher. Undefined PBPs remain below 10 percent for all CSLs. For this design line, PBPs increase monotonically from 2 to 38 years with increasing CSL.

**Table 11.4.8 Rural Cooperatives Subgroup Payback Period Results: Design Line 3**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Mean Payback (Years) | 1.6 | 5.7 | 13.7 | 22.5 | 33.9 | 37.7 |
| Transformers Not Impacted by Standard (%) | 72.4 | 64.9 | 49.4 | 2.3 | 0.1 | 0.0 |
| Transformers having Well-Defined Payback (%) | 17.5 | 34.7 | 49.8 | 95.8 | 99.9 | 100.0 |
| Transformers having Undefined Payback (%) | 10.2 | 0.5 | 0.8 | 2.0 | 0.0 | 0.0 |
| Mean Incremental First Cost ($) | 132 | 615 | 1,310 | 1,859 | 8,319 | 9,393 |
| Mean Operating Cost Savings ($) | 219 | 220 | 204 | 157 | 315 | 318 |

#### 11.4.2.4 Design Line 4 Payback Period Results

Table 11.4.9 presents the summary of the LCC subgroup analysis for rural cooperatives for the representative unit from design line 4, a 150 kVA, liquid-immersed, three-phase distribution transformer. For this unit, the Department forecasts that more than 63 percent of the transformers are not impacted by CSL 1, while more than 93 percent of transformers are impacted by a CSL 3 standard level or higher. Undefined PBPs remain below two percent of transformers for all CSLs. Mean distribution PBP ranges from 11 to 38 years; the Department calculated the lowest mean PBP for CSL 1.

**Table 11.4.9 Rural Cooperatives Subgroup Payback Period Results: Design Line 4**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| Mean Payback (Years) | 10.8 | 22.2 | 25.4 | 18.0 | 31.4 | 37.7 |
| Transformers Not Impacted by Standard (%) | 63.1 | 38.5 | 5.7 | 6.1 | 0.6 | 0.0 |
| Transformers having Well-Defined Payback (%) | 35.3 | 59.8 | 94.2 | 93.8 | 98.9 | 99.8 |
| Transformers having Undefined Payback (%) | 1.6 | 1.7 | 0.1 | 0.0 | 0.6 | 0.2 |
| Mean Incremental First Cost ($) | 475 | 878 | 1,545 | 1,957 | 3,402 | 4,276 |
| Mean Operating Cost Savings ($) | 75 | 69 | 88 | 123 | 135 | 141 |

#### 11.4.2.5 Design Line 5 Payback Period Results

Table 11.4.10 presents the summary of the LCC subgroup analysis for rural cooperatives for the representative unit from design line 5, a 1500 kVA, liquid-immersed, three-phase distribution transformer. For this unit, the Department forecasts that nearly 71 percent of the transformers are not impacted by CSL 1, while more than 79 percent of transformers are impacted by a CSL 4 standard level or higher. Undefined PBPs remain two percent or fewer of transformers for all CSLs. Mean distribution PBP ranges from 5 to 29 years and increases monotonically with increasing CSL.

**Table 11.4.10 Rural Cooperatives Subgroup Payback Period Results: Design Line 5**

| | Candidate Standard Level | | | | | |
|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** |
| Mean Payback (Years) | 4.9 | 8.4 | 16.9 | 17.4 | 29.4 | 29.4 |
| Transformers Not Impacted by Standard (%) | 70.9 | 62.4 | 39.6 | 20.8 | 0.0 | 0.0 |
| Transformers having Well-Defined Payback (%) | 29.0 | 37.4 | 58.5 | 78.7 | 99.8 | 99.9 |
| Transformers having Undefined Payback (%) | 0.1 | 0.2 | 2.0 | 0.5 | 0.1 | 0.1 |
| Mean Incremental First Cost ($) | 1,486 | 2,576 | 3,014 | 4,400 | 20,006 | 19,934 |
| Mean Operating Cost Savings ($) | 440 | 503 | 393 | 419 | 853 | 845 |

## REFERENCES

1. U.S. Department of Energy - Energy Information Administration. *Form EIA-861: Annual Electric Utility Data.* 2003. (Last accessed September, 2005.) This material is available in Docket #86. Contact Ms. Brenda Edwards-Jones, U.S. Department of Energy, Building Technologies Program, Mailstop EE-2J, 1000 Independence Avenue, SW, Washington, DC, 20585-0121, telephone (202) 586-2945 for more information. <http://www.eia.doe.gov/cneaf/electricity/page/eia861.html>