# Lighting Energy Conservation Potential

Lighting, as already noted in this report, is a major focus of conservation efforts in the commercial sector. The statistical profile developed in the previous section provides a basis for estimating the potential for lighting energy conservation under various assumptions. A simple estimation procedure utilizing that profile is described next. The procedure is then applied under various assumptions about the conservation measures adopted.

Using the estimates described above (and presented in Tables 1 through 9 of the Detailed Tables) the savings estimation procedure described below could be implemented under other conservation assumptions. The different conservation cases evaluated in this report vary both in terms of what changes are assumed implemented, and in terms of the impact assumed for each change. These varying assumptions are designed to cover a range of plausible situations. Nonetheless, arguments could certainly be made for impacts outside the ranges considered here, as well as for implementing other changes.

No assessment of cost-effectiveness is made for any of the cases considered. The changes suggested by a cost-effectiveness analysis might be less extensive, more radical, or simply different from any of the combinations considered here. In addition, actual changes would not occur instantaneously, as implicitly assumed by the analysis here.

As noted earlier, the base estimate of commercial lighting energy is also subject to wide variation depending on technical assumptions. To avoid undue dependence on these assumptions, particularly the illuminance assignments, the conservation estimates are presented primarily in terms of the percentage of lighting energy saved. Uniformly higher or lower base-case illuminance assignments would yield the same percentage savings, though substantially different absolute savings. The percent savings are translated into approximate energy amounts at the end, to indicate the magnitude of the impact.

## Savings Estimation Methodology

*Savings are estimated by computing the percent reduction according to the equipment currently in place and the assumed improved technology or practice adopted. Since the statistical profile provides estimates of energy use for each lighting equipment configuration, savings estimates are easily calculated under alternate assumptions.*

Potential lighting energy savings are evaluated for several conservation cases. Each case is defined by an assumed equipment replacement scheme, together with the assumed effects of the conservation features adopted under that scheme. For each conservation case an overall deflation factor is computed for each of the five lamp types considered for the base case energy calculations. The overall deflation factor is obtained as the product of the deflation factors for the conservation features adopted.

Applying the deflation factor to the base case energy gives the estimated energy use by that lamp type after implementing the assumed replacements. From the conservation-case energy estimates for each lamp type, the total energy use after replacements and the percent savings relative to the base case are obtained.

This procedure is kept relatively simple because the base case assumes no effect of conservation features in place. Under this assumption, the deflation factors depend only on the lamp type. Under an alternate base case, assuming some conservation effect for the features currently in place, different overall deflation factors would be computed for each lighting configuration (combination of lamp type with conservation features). The same basic method would still apply. The procedure is described in more detail in Appendix E.

**Formal Specification:**

For lamp type **L**, to be replaced by lamp type **L***, the overall deflation factor is computed as

$$\mathbf{d} \quad = \quad (\mathbf{Q_L/Q_{L*}})\ [\mathbf{d_{CTL}}]\ [\mathbf{d_{HEB}}]\ [\mathbf{d_{RFL}}]\ [\mathbf{d_{DEL}}],$$

where $\mathbf{Q_L}$ is the efficacy of lamp type **L**, and $\mathbf{d_{CTL}}$, $\mathbf{d_{HEB}}$, $\mathbf{d_{RFL}}$, and $\mathbf{d_{DEL}}$, respectively, indicate the deflation factors for controls, high-efficiency ballasts, reflectors, and delamping. The square brackets indicate that the deflation factor $\mathbf{d_f}$ is included in the product if (and only if) feature **f** is adopted for that lamp type under the replacement scheme. Each equipment replacement scheme assumes that all lamps of a given type **L** are changed to the designated replacement **L***. Selection of the modest and optimistic values of the deflation factors is discussed in Appendix C.

# Savings Potential

*Converting all incandescent bulbs to compact fluorescent lamps with reflectors saves close to 30 percent of the base case lighting energy, with the conservation effects assumed for this analysis. A complementary scheme excludes compact fluorescents but converts all equipment to the most energy-efficient version of that specific lamp type, together with lighting controls. This scheme is estimated to save 30 to 50 percent of the base case lighting energy without reducing illumination levels. The most extreme conservation case considered for this analysis indicates savings of nearly 80 percent of the base case lighting energy. This case includes lighting controls and extensive reductions in illumination, as well as universal lamp replacement by more efficient equipment. All these estimates depend heavily on the effectiveness (including penetration) assumed for the conservation measures.*

## Equipment Replacement Schemes

The potential energy savings that would be obtained by converting commercial floorspace to more efficient lighting equipment is evaluated for several different conservation cases. Three basic equipment replacement schemes are considered (Figure 13). Each of the three basic schemes is evaluated at the more modest and at the more optimistic assumed conservation effects, with and without delamping.

Each conservation feature applied in a building is assumed to apply uniformly to all floorspace lighted by equipment that can use the feature. That is, the effect assumed for each feature is an average over all applicable floorspace; lower penetration would correspond to a lower assumed effect.

The no-delamping cases assume that whatever lighting levels currently exist are to be maintained. The delamping cases assume that substantial fractions of floorspace are currently overlit, so that average lighting levels could be reduced without loss of amenity or productivity. The extent of delamping adopted for the conservation case is also assumed at a modest (10 percent) and an optimistic (25 percent) level.

The first replacement scheme considered (*comprehensive*) represents a replacement of all existing lighting equipment with a more efficient counterpart. The second (*compact fluorescent conversion only*) represents the effect of a single, very commonly considered strategy. The third scheme serves as a complement to the second, to indicate what can be accomplished without that dominating effect.

Specifically, the three replacement schemes are defined as follows.

**1) Comprehensive**. All lighted floorspace is converted to the most efficient possible equipment of the same type. Fluorescent lamps are converted to very-high efficiency fluorescent lamps with high-efficiency ballasts and reflectors. Incandescent lamps are all converted to compact fluorescents with reflectors. High-intensity discharge lamps are assumed to be metal halide currently, and to convert to the more efficient high-pressure sodium.

**2) Compact Fluorescent Conversion Only**. A substantial fraction of the savings from the comprehensive scheme are due to the conversion of incandescent bulbs to compact fluorescents. To examine this effect, standard and energy-efficient incandescents are assumed to be replaced by compact fluorescent lamps with reflectors, with no other changes.

**3) Comprehensive Improvements Without Compact Fluorescent Conversions.** As a complement to scheme (2), this replacement scheme assumes all the changes of the comprehensive scheme (1), except that incandescent bulbs are not converted to compact fluorescent lamps. Instead, incandescent bulbs are converted to energy-efficient incandescents with controls.

**Figure 13. Schematic of Equipment Replacement Schemes**

| | | Equipment Replacement Scheme | | |
|---|---|---|---|---|
| Lamp Type | Conservation Features | (1) Comprehensive | (2) Compact Fluorescent Conversion Only | (3) Comprehensive Improvement Without Compact Fluorescent Conversions |
| Incandescent | | | | |
| | Controls | X | | X |
| | Compact Fluorescent | X | X | |
| | Reflector | X | X | |
| | Energy-Efficient Bulb | | | X |
| Fluorescent | | | | |
| | Controls | X | | X |
| | High-Efficiency Ballast | X | | X |
| | Very-High Efficiency Lamp | X | | X |
| | Reflector | X | | X |
| High-Intensity Discharge (HID) | | | | |
| | Controls | X | | X |
| | High-Pressure Sodium | X | | X |

X = Addition of or conversion to this feature is assumed under the indicated scheme, for all floorspace lighted by the indicated lamp type.

Note: For the base case, controls, high-efficiency ballasts, reduced illumination (delamping), and reflectors are assumed to serve negligible fractions of floorspace, even though present for some buildings. High-intensity discharge lamps are assumed to be metal halide in the base case, and to convert to high-pressure sodium under schemes (1) and (3).

**Formal Specification:**
The overall deflation factors for the replacement schemes with no delamping are:

| | (1) Comprehensive | (2) Compact Fluorescent Conversion Only | (3) Comprehensive Improvements without Compact Fluorescent Conversions |
|---|---|---|---|
| **Fluorescent:** | $(Q_L/Q_{VHE})\ d_{RFL}\ d_{HEB}\ d_{CTL}$ | 1.0 | $(Q_L/Q_{VHE})\ d_{RFL}\ d_{HEB}\ d_{CTL}$ |
| **Incandescent:** | $(Q_L/Q_{CF})\ d_{RFL}\ d_{CTL}$ | $(Q_L/Q_{CF})\ d_{RFL}$ | $(Q_L/Q_{EEI})\ d_{CTL}$ |
| **HID:** | $(Q_{MH}/Q_{HPS})\ d_{CTL}$ | 1.0 | $(Q_{MH}/Q_{HPS})\ d_{CTL}$ |

With illuminance reductions (delamping) all the above deflation factors are multiplied by the delamping deflation factor $\mathbf{d_{DEL}}$.

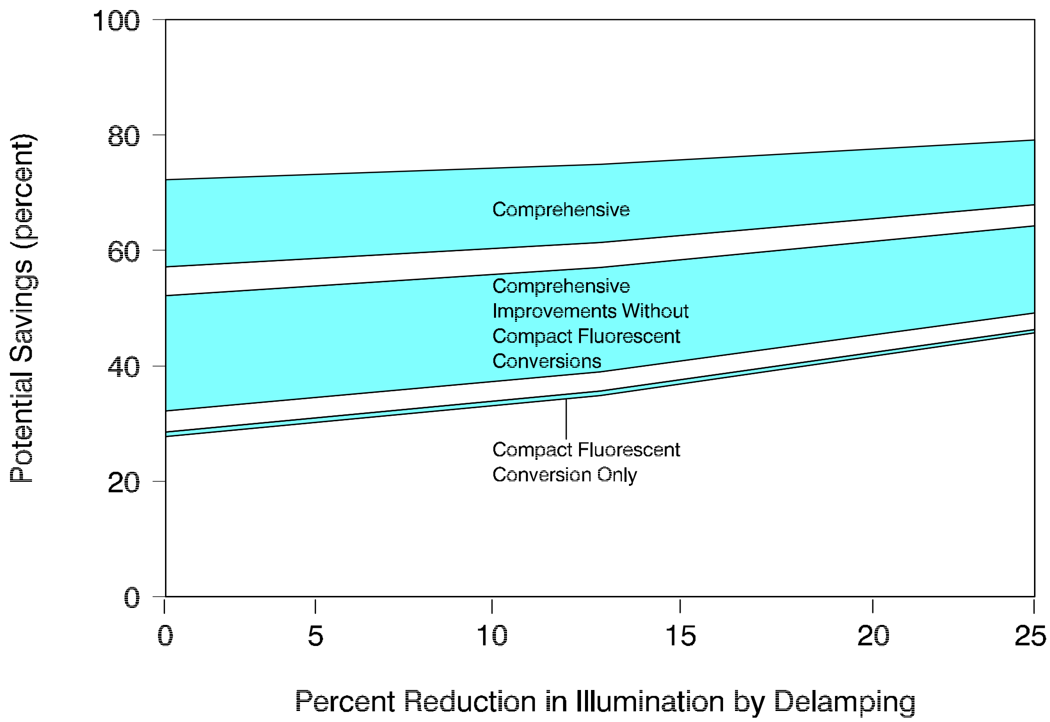
## Results

The most drastic conservation case considered was the comprehensive replacement scheme with the optimistic assumptions for the conservation effects, including delamping. For this case, potential savings are estimated at nearly 80 percent of current (1986) use (Figure 14). Savings of close to 30 percent of current use come from converting incandescent bulbs to compact fluorescent lamps with reflectors (scheme 2). With compact fluorescent conversions excluded, but all other replacements made (scheme 3), savings estimates are in the range of 30 to 50 percent with no delamping, and as high as 64 percent with optimistic conservation effects and delamping. (See Table 12 of the "Detailed Tables" section.)

Different lamp types dominate the savings under different replacement schemes. (See Table 10 of the Detailed Tables for savings estimates by lamp type under the no-delamping conservation cases.) Under the schemes that include compact fluorescent conversions, the amount of energy saved by converting space currently served by incandescent bulbs to better equipment (including controls) is between 90 and 100 billion kWh. (See Table 10 of the Detailed Tables.) A comparable amount is saved by improving the equipment for space currently lighted by fluorescent lamps, but the savings for incandescents amounts to about three-quarters of their base case use. (See Table 11 of the Detailed Tables). Under the third replacement scheme, which excludes compact fluorescents, the savings for incandescent bulbs are from controls only, and contribute relatively little to the total savings.

In total, the savings under the most drastic conservation case considered would be about 254 billion kWh, or 0.9 quadrillion Btu. Under the least effective case, the potential savings estimate translates into about 89 billion kWh, or 0.3 quadrillion Btu.

**Figure 14. Range of Potential Savings for Various Conservation Cases**




Note: A conservation case is defined by an equipment replacement scheme together with an assumed effect of conservation features and reduction in illumination. Each band shows the range of estimated savings from the modest to the optimistic assumptions for the effect of conservation features, as described in Appendix C. The equipment replacement schemes are:

(1) Comprehensive: highest efficiency fluorescent and high-intensity discharge lamps and equipment; incandescent bulbs converted to compact fluorescent with reflectors; lighting controls on all lamps;

(2) Compact Fluorescent Conversion Only: incandescent bulbs converted to compact fluorescent with reflectors; no lighting controls;

(3) Comprehensive Improvement Without Compact Fluorescent Conversions: highest efficiency fluorescent, incandescent and high-intensity-discharge lamps and equipment; no conversions of incandescent to compact fluorescent; lighting controls on all lamps.

The potential savings are shown for each case as a percent of the base case lighting energy estimate (321.4 billion kilowatthours).

Sources: Adapted from Energy Information Administration, Office of Energy Markets and End Use, Form EIA-871A, "Building Questionnaire" of the 1986 Nonresidential Buildings Energy Consumption Survey; and sources described in Appendices B and C.

## Sensitivity Test

Savings estimates for all cases were recomputed assuming a uniform illuminance and uniform lighting hours across all buildings. This set of computations was performed as a check on the sensitivity of the results to the illuminances assumed and the method of estimating lighting hours. For the Comprehensive and Compact Fluorescent Conversion Only schemes (1 and 2), savings estimates were three to four percentage points higher, corresponding to a 5 to 10 percent increase in the savings estimated. For the scheme (3) that allowed no compact fluorescent conversion, assuming illuminance and hours were uniform made essentially no difference in the estimate of potential savings.

Thus, while the assignment of illuminance to buildings is not precise, errors in these assignments do not appear to affect the estimates of potential savings, expressed as a percent of total current lighting energy. In absolute terms, of course, the illuminance assumptions directly affect the estimates of both energy and savings.

Consideration of the illuminances affects the potential savings estimates primarily by indicating a lower effect of converting incandescent bulbs to compact fluorescent lamps than would be obtained by ignoring illuminance differences. The association of more efficient (i.e., nonincandescent) lighting equipment with higher illuminances means that a smaller fraction of energy is currently supplied by incandescent bulbs, hence less can be achieved by converting these bulbs to more efficient equipment.