Appendix E

Savings Estimation Methodology

Savings are estimated for several conservation cases. Each conservation case is defined by an equipment replacement scheme together with the assumed effects of conservation features and extent of delamping (reduction in illuminance).

Each equipment replacement scheme defines the lamp types **L*** and conservation features **f*** that are to be adopted. A different collection of equipment replacements is assumed for each lighting configuration currently in place.

For each current lighting configuration **c** (defined by a lamp type **L** together with conservation features **f**) the base estimate of energy consumption is adjusted by an overall deflation factor. The overall deflation factor $\mathbf{d}_{c/c*}$ is obtained as the product of deflation factors for each of the lamp replacements or conservation feature adoptions under the scheme. Thus,

$$\mathbf{d}_{c/c*} = \frac{\mathbf{Q}_L}{\mathbf{Q}_{L*}} \frac{\mathbf{d}_{CTL(c*)}}{\mathbf{d}_{CTL(c)}} \frac{\mathbf{d}_{HEB(c*)}}{\mathbf{d}_{HEB(c)}} \frac{\mathbf{d}_{RFL(c*)}}{\mathbf{d}_{RFL(c)}} \frac{\mathbf{d}_{DEL(c*)}}{\mathbf{d}_{DEL(c)}} \quad \textbf{(21)}$$

where **CTL**, **HEB**, **RFL**, and **DEL**, respectively, refer to lighting controls, high-efficiency ballasts, reflectors, and delamping, and $\mathbf{d}_{f(c)}$ indicates the assumed effect of feature **f** for configuration **c**.

This general formulation allows each conservation feature **f** to have different assumed effects depending on the lighting configuration considered. The feature could also have different assumed effect before and after the replacement is implemented, for example, if the replacement assumes greater penetration within buildings where the feature is already in place. If feature **f** is assumed not to be adopted or to have negligible effect, $\mathbf{d}_{f(c)}$ is set equal to 1.

For the base case energy calculation, the effect of all conservation features currently in place is assumed to be negligible, as an average over all floorspace that might be affected. Thus, for the savings calculations presented, the overall deflation factors are computed as:

$$\mathbf{d}_{c/c*} = \frac{\mathbf{Q}_L}{\mathbf{Q}_{L*}} \mathbf{d}_{CTL(c*)} \mathbf{d}_{HEB(c*)} \mathbf{d}_{RFL(c*)} \mathbf{d}_{DEL(c*)}. \quad \textbf{(22)}$$

This expression can also be written as:

$$\mathbf{d}_{c/c*} = (\mathbf{Q}_L/\mathbf{Q}_{L*}) [\mathbf{d}_{CTL}] [\mathbf{d}_{HEB}] [\mathbf{d}_{RFL}] [\mathbf{d}_{DEL}], \quad \textbf{(23)}$$

where the square brackets indicate that the deflation factor $\mathbf{d}_f$ is included in the product only if feature **f** is adopted for current configuration c under the replacement scheme.

Because the presence of controls, high-efficiency ballasts, and delamping are ignored in the base case, configurations are distinguished only by lamp type currently in place. Thus, only five different deflation factors are required for each conservation case examined here, one for each of the lamp types identified as currently in place.

The overall deflation factor $\mathbf{d_{c/c*}}$ is applied to the base case energy estimate $\mathbf{E_c}$ for lighting configuration **c** to give the after-replacement energy estimate $\mathbf{E_{c*}}$ for that configuration. Subtracting from the base case estimate gives the savings.

$$\mathbf{SV_c} = \mathbf{E_c - E_{c*}} \quad \textbf{(24)}$$

$$= \mathbf{E_c - d_{c/c*}\, E_c} \quad \textbf{(25)}$$

$$= \mathbf{(1 - d_{c/c*})\, E_c.} \quad \textbf{(26)}$$

Summing savings over configurations gives total lighting energy savings for that case.

$$\mathbf{SV_T} = \mathbf{\Sigma_c\, SV_c.} \quad \textbf{(27)}$$

The percent savings for a particular lighting configuration is obtained directly from the overall deflation factor as

$$\mathbf{SV\%_c} = \mathbf{100\ (1\text{-}d_{c/c*}).} \quad \textbf{(28)}$$

For the commercial buildings population as a whole, the percent savings is obtained by dividing the total after-replacement energy estimate by the base case estimate of total lighting energy:

$$\mathbf{SV\%_T} = \mathbf{100\ (1 - E_{T*} / E_T).} \quad \textbf{(29)}$$

The overall percent savings can also be expressed as the weighted average of the savings for the individual configurations:

$$\mathbf{SV\%_T} = \mathbf{\Sigma_c\, SV\%_c\ (E_c / E_T).} \quad \textbf{(30)}$$

Alternate Savings Estimate: A Sensitivity Check

The least verifiable component of the energy and savings computations is the illuminance **I** assigned to the building. If the illuminances assumed are too high or too low by a consistent factor, the resulting savings estimates would be off by that factor in absolute terms, but would be unaffected in percentage terms. However, if the errors in the illuminance assignments are inconsistent across building types, even the percent savings estimates could be distorted.

To test the sensitivity of the estimated percent savings to the relative illuminances assumed, the computations are repeated assuming that the time-averaged illuminance **T** is independent of the type of equipment or building. The independence assumption does not require that lighting levels and hours of use be the same for all buildings, only that the differences among buildings be unrelated to the types of equipment. Realistically, though, certain types of lighting equipment are more likely to be used in certain applications, depending in part on the hours of use and lighting levels.

Re-expressing the total percent savings formula above gives

$$\mathbf{SV\%_T} = \frac{\Sigma_c \, \mathbf{SV\%_c \, S_c \, I_c \, U_c \, / \, Q_L}}{\Sigma_c \, \mathbf{S_c \, I_c \, U_c \, / \, Q_L}} . \qquad \textbf{(31)}$$

With a constant assumed for the illuminance **I** and usage factor **U**, this formula becomes simply

$$\mathbf{SV\%_T} = \frac{\Sigma_c \, \mathbf{SV\%_c \, S_c \, / \, Q_L}}{\Sigma_c \, \mathbf{S_c \, / \, Q_L}} . \qquad \textbf{(32)}$$

Thus, with differences in illuminance and hours ignored, the percent savings can be estimated knowing for each lighting configuration only the deflation factor $\mathbf{d_c}$, efficacy $\mathbf{Q_c}$, and floorspace served $\mathbf{S_c}$. In fact, the efficacy does not need to be known in absolute terms, only relative to some standard. This was the approach used in an earlier stage of this analysis.[9]

As discussed in the text, the results of the alternate savings estimate indicated that ignoring differences in **T** resulted in an overstatement of the potential savings, on the order of 5 to 10 percent of the savings estimate that incorporated these differences.