

**2**

# M&V Guidelines for Lighting Efficiency Measures with Controls

## 2.1 Overview

The lighting projects covered by this M&V procedure are lighting efficiency measures in combination with lighting controls retrofit measures. Lighting efficiency measures may include the replacement of existing lamps and ballasts with new energy efficient lamps and ballasts. Controls measures may be occupancy sensors or daylighting controls. Stand-alone lighting controls measures are not eligible for incentives under this program because they do not significantly contribute to peak demand savings.

Demand savings are based on coincident-load factors and changes in lighting load as determined using lighting fixture wattage values listed in the CenterPoint Energy Table of Standard Fixture Wattages (see Appendix C). Energy savings are determined by subtracting the product of post-installation lighting load and operating hours from the pre-installation lighting load and operating hours for each applicable usage group or circuit in the project. Changes in lighting load are determined using lighting fixture wattage values indicated in the Table of Standard Fixture Wattages.

The Sponsor should establish pre- and post-installation operating hours using one of the following methods:

**Stipulated Control Savings Method** – Use stipulated operating hours and Coincidence Factor (CF), depending on building type. Use a stipulated Power Adjustment Factor (PAF) depending on type of lighting control (see Section 2.2 of this chapter).

**Full M&V Method for Lighting Controls** – Meter pre- and/or post-installation operating hours using defined sampling techniques (see Section 2.3 of this chapter). Calculate the CF from metered data.

The method selected and the rigor of the M&V activities are a function of the project site conditions and savings potential.

The demand and energy savings due to the reduction of lighting load on cooling equipment are stipulated. The demand savings are **10%** of the connected lighting load demand reduction, and the energy savings are **5%** of the connected lighting load energy reduction. These savings may only be claimed in conditioned spaces.

In addition to determining operating hours, the Project Sponsor is required to conduct pre- and post-installation equipment surveys. The Project Sponsor should fill out and submit survey results in the Retrofit Lighting Inventory Form using fixture codes provided in the Table of Standard Fixture Wattages. CenterPoint Energy or its contractor will conduct pre- and post-installation inspections to verify the reported baseline and retrofit conditions, respectively.

## 2.2 Stipulated Control Savings Method

This method requires the use of the appropriate stipulated hours from Table 2.1 and a PAF from Table 2.2. If values from these tables do not accurately characterize the building type

and operation, then the Project Sponsor should refer to the *Full M&V Method for Lighting Controls* in Section 2.3 of this chapter for an appropriate M&V technique.

**Table 2.1: Stipulated Operating Hours, Coincidence Factors, and Interactive Savings**

Building Type	Stipulated Annual Operating Hours	Avg. On-Peak Demand Coincidence Factor	Interactive HVAC Demand Savings	Interactive HVAC Energy Savings
<b>24-Hour Supermarket/Retail</b>	6,900	95%	10%	5%
<b>College/University</b>	2,085	67%	10%	5%
<b>Education (K-12; no summer session)</b>	2,150	82%	10%	5%
<b>In-Patient Health Care</b>	3,750	60%	10%	5%
<b>Multi-Family Housing, Common Areas</b>	4,772	87%	10%	5%
<b>Non 24-Hour Supermarket/Retail/Restaurant</b>	4,250	95%	10%	5%
<b>Office</b>	3,760	80%	10%	5%
<b>Parking Structure</b>	7,884	100%	0%	0%

The first column in Table 2.1 presents the stipulated, whole-building, annual operating hours for the building types listed. The retrofit energy savings are determined from the operating hours and the kW reduction determined from the lighting tables. The average on-peak demand CF in the second column is the ratio of the average on-peak operating hours of all lighting circuits to the total number of CenterPoint Energy on-peak hours, during the monitoring period. The retrofit demand savings are determined from the CF in column two and the kW reduction determined from the Table of Standard Fixture Wattages.

**Table 2.2: Power Adjustment Factors (PAFs)\***

Control Type	PAF
Daylight controls (DC) – continuous dimming	0.70
DC – multiple-step dimming	0.80
DC – ON/OFF	0.90
Occupancy sensor (OS)	0.70
OS w/ DC – continuous dimming	0.60
OS w/ DC – multiple-step dimming	0.65
OS w/ DC – ON/OFF	0.65

\*PAFs are adapted from ASHRAE Standard 90.1-1989, Table 6-3.

The PAF represents the average reduction in operating hours as a result of installing lighting controls. Multiplying the pre-retrofit (stipulated or measured) lighting operating hours by the PAF for a given control type gives the post-retrofit hours.

## 2.2.1 Pre-Installation M&V Activities

### 2.2.1.1 Pre-Installation Equipment Survey

Prior to installing the lighting retrofit, the Project Sponsor conducts a pre-installation equipment survey, to be submitted as part of the Final Application. The purpose of the pre-installation equipment survey is to inventory all existing lighting equipment, and to specify the replacement equipment. This survey should provide the following information about all fixtures: room location, fixture, lamp, and ballast types, lighting controls, area designations, counts of operating and non-operating fixtures, type of control device, and whether the space is conditioned or unconditioned. Surveys should include all baseline lighting fixtures and controls, regardless of whether they will be retrofitted. Fixture wattages should be based on the Table of Standard Fixture Wattages. This information should be tabulated electronically in the Retrofit Lighting Inventory Form. Refer to Section II, Chapter 4 of the Program Manual for an explanation of the Retrofit Lighting Inventory Form.

*Non-operating fixtures*

**The number of non-operating baseline fixtures will be limited to 10% of the total fixture count per facility.** If, for example, more than 10% of the total number of fixtures is inoperative, the number of fixtures beyond 10% will be assumed to have a baseline fixture wattage of zero. Thus the total baseline demand for the project will be adjusted accordingly.

### 2.2.1.2 Pre-Installation Inspection

CenterPoint Energy or its contractor will conduct a pre-installation inspection to verify that the Sponsor has properly documented the baseline. The criterion for baseline acceptance is that the installed demand of the inspected sample must be within  $\pm 5\%$  of the demand reported on the lighting survey form. If the error exceeds  $\pm 5\%$ , the Sponsor is allowed to resubmit corrected lighting tables. If the project fails inspection twice due to incorrect survey forms, the Project Sponsor will bear the cost of subsequent inspections.

The pre-installation operating hours are not measured as part of the pre-installation M&V activities for the **Stipulated Controls Savings Method**. The stipulated pre-installation annual operating hours are listed in Table 2.1. If these tables do not accurately characterize the building type, then the Project Sponsor should refer to the *Full M&V Method Lighting Controls* in Section 2.3 of this chapter for the appropriate M&V techniques for measuring operating hours.

## 2.2.2 Post-Installation M&V Activities

### 2.2.2.1 Post-Installation Equipment Survey

The Sponsor is required to conduct a post-installation lighting equipment survey as part of the Installation Report (IR). The purpose of the post-installation equipment survey is to inventory the actual installed replacement equipment. Fixture wattages shall be based on the Table of Standard Fixture Wattages. In the IR, the proposed equipment information listed in the approved Final Application (FA) should be updated to reflect the actual post-retrofit conditions and equipment found during the survey after installation. Any equipment listed in the approved FA that was not in fact replaced should remain in the lighting equipment inventory – in this case simply copy the pre-retrofit information to the post-retrofit columns.

### 2.2.2.2 Post-Installation Inspection

CenterPoint Energy or its contractor will conduct a post-installation inspection to verify that the retrofit was installed as reported. In most cases, CenterPoint Energy or its contractor will inspect statistically significant samples taken from the entire lighting population. The

criterion for acceptance is that the installed demand of the sample must be within ±5% of the demand submitted on the post-installation survey form. If significant errors are found that cause the error to be greater than 5%, CenterPoint Energy will inform the Sponsor that the lighting survey table must be corrected and resubmitted, citing the major cause of the errors found.

**2.2.2.3 Operating Hours**

The **Stipulated Controls Savings Method** uses stipulated annual operating hours and PAFs as listed in Table 2.1 and Table 2.2, respectively. The post-installation operating hours are the product of the stipulated pre-installation hours and the PAF corresponding to the installed control type. Note that the PAF for usage groups with no controls is 1.0, so the pre- and post-installation operating hours are equal. If these tables do not accurately characterize the building or control types under consideration, then the Project Sponsor should refer to the *Full M&V Method Lighting Controls* in Section 2.3 of this chapter for the appropriate M&V techniques for measuring operating hours.

**2.2.3 Calculation of Demand and Energy Savings**

The peak demand savings and energy savings are calculated according to Equations 2.1 through 2.6. Demand savings are only allowed for lighting fixtures that will be in operation on weekdays between the hours of 1 PM and 7 PM during the months of May through September. Total demand savings are calculated by multiplying the kW savings by the CF for the appropriate building type, from Table 2.1. The CF is used to adjust total installed lighting demand for the actual percentage of fixtures operating during CenterPoint Energy’s peak demand hours. The CF is also applied to the interactive savings since interactive savings are a direct result of lighting operation. The PAF is applied to the pre-retrofit (stipulated or measured) lighting operating hours for a given control type, resulting in the post-retrofit hours. No demand savings are credited to the controls.

Interactive HVAC demand and energy savings may be calculated only for lighting retrofits taking place in air-conditioned spaces. Lighting retrofits in unconditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments. For eligible projects, the interactive HVAC demand savings is **10%** of the lighting demand savings. Similarly, the interactive HVAC energy savings is equal to **5%** of the lighting energy savings.

**2.2.3.1 Peak Demand Savings**

Equation 2.1:

$\text{Connected Lighting Load Reduction [kW]} = \text{Pre Lighting Demand [kW]} - \text{Post Lighting Demand [kW]}$
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Equation 2.2:

$\text{Interactive HVAC Demand Savings [kW]} = \text{Connected Lighting Load Reduction [kW]} * 0.10$
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Equation 2.3:

$$\text{Total Demand Savings [kW]} = (\text{Connected Lighting Load Reduction [kW]} + \text{Interactive HVAC Demand Savings [kW]}) * \text{Coincidence Factor}$$

### 2.2.3.2 Energy Savings

Equation 2.4:

$$\text{Lighting Energy Savings [kWh]} = \{ \text{Pre Lighting Demand [kW]} - \text{Post Lighting Demand [kW]} * \text{PAF[\%]} \} * \text{Stipulated Annual Operating Hours [hrs]}$$

Equation 2.5:

$$\text{Interactive HVAC Energy Savings [kWh]} = \text{Lighting Energy Savings [kWh]} * 0.05$$

Equation 2.6:

$$\text{Total Energy Savings [kWh]} = \text{Lighting Energy Savings [kWh]} + \text{Interactive HVAC Energy Savings [kWh]}$$

### 2.2.4 Example

The following is an example of how the M&V procedures described above would be applied using the Stipulated Controls Savings Method to determine the operating hours and annual energy savings.

**Example\***

A lighting efficiency and controls project is proposed for a typical small office building. Controls are to be installed in some common offices and private offices. The Project Sponsor submits the lighting survey detailing the existing and proposed equipment inventory. The following table summarizes the existing and proposed connected lighting load and operating hours for each usage group in the project. For office buildings, the stipulated operating hours is 3,760 hrs and the CF is **80%**.

Area Description	Connected Load (kW)		New control type	PAF (Table 2.2)	Pre-retrofit hours (Table 2.1)
	Existing	Proposed			
Common Offices w/ controls	9.0	4.3	Daylight control—multi-step dimming	0.8	3,760
Common Offices	10.1	4.1	n/a	1.0	3,760
Private Offices	5.2	2.1	n/a	1.0	3,760
Private Offices w/controls	4.3	2.0	Occupancy sensor	0.7	3,760
Conference Rooms	3.9	1.5	n/a	1.0	3,760
Restrooms <sup>†</sup>	0.3	0.1	n/a	1.0	3,760

\* Projects that consist of only lighting measures receive 65% of the total incentive.

<sup>†</sup> The stipulated hours for a particular building type are averaged to include all usage types.

Pre-retrofit operating hours are determined using the **Stipulated Hours Method**. The stipulated annual operating hours for office buildings is 3,760 hours/year. Usage groups that are being retrofitted with controls are divided into control and non-control usage groups. The pre-retrofit hours for the control usage groups are multiplied by the PAF corresponding to the type of control installed. The post-retrofit hours for the non-control usage groups remain unchanged from the pre-retrofit hours. Using Equations 2.1 through 2.6, the energy savings for the *Common Offices With Controls* will be

- (a) Connected Lighting Load Reduction [kW] = 9.0 [kW] – 4.3 [kW] = **4.7 [kW]**
- (b) Interactive HVAC Demand Savings [kW] = 4.7 [kW] \* 0.10 = **0.5 [kW]**
- (c) Total Demand Savings [kW] = (4.7 [kW] + 0.5 [kW]) \* 0.80 = **4.2 [kW]**
- (d) Lighting Energy Savings [kWh] = {9.0 [kW] – 4.3 [kW] \* 0.8} \* 3,760 [hrs] = **20,906 [kWh]**
- (e) Interactive HVAC Energy Savings [kWh] = 20,906 [kWh] \* 0.05 = **1,045 [kWh]**
- (f) Total Energy Savings [kWh] = 20,906 [kWh] + 1,045 [kWh] = **21,951 [kWh]**

The energy savings is then calculated for each usage group.

Area Description	Results					
	(a)	(b)	(c)	(d)	(e)	(f)
<b>Common Offices w/ Controls</b>	<b>4.7</b>	<b>0.5</b>	<b>4.2</b>	<b>20,906</b>	<b>1,045</b>	<b>21,951</b>
Common Offices	6.0	0.6	5.3	22,560	1,128	23,688
Private Offices	3.1	0.3	2.7	11,656	583	12,239
Private Offices w/ Controls	2.3	0.2	2.0	10,904	545	11,449
Conference Rooms	2.4	0.2	2.1	9,024	451	9,475
Restrooms	0.2	0	0.2	752	38	789
<b>Total</b>			<b>16.5</b>			<b>79,591</b>

## 2.3 Full M&V Method for Lighting Controls

This measurement and verification (M&V) procedure is appropriate for projects that involve the installation of lighting controls in combination with the replacement of existing lamps and ballasts. This method requires the Project Sponsor to meter the operating hours of a statistically significant sample of fixtures both before and after measure installation.

The demand and energy savings due to the reduction of lighting load on cooling equipment are stipulated. The demand savings is **10%** of the connected lighting load demand reduction, and the energy savings is **5%** of the connected lighting load energy reduction. These savings may only be claimed in conditioned spaces.

### 2.3.1 Pre-Installation M&V Activities

#### 2.3.1.1 Pre-Installation Equipment Survey

Prior to installing the lighting retrofit, the Project Sponsor conducts a pre-installation equipment survey, to be submitted as part of the FA. The purpose of the pre-installation equipment survey is to inventory all existing lighting equipment, and to specify the replacement equipment. Surveys shall include all baseline lighting fixtures and controls, regardless of whether they will be retrofitted. Fixture wattages should be based on the Table of Standard Fixture Wattages. This information should be organized by usage group and tabulated electronically in the Retrofit Lighting Inventory Form. Refer to Section II, Chapter 4 of this manual for an explanation of the Retrofit Lighting Inventory Form.

#### *Non-Operating Fixtures*

**The number of non-operating baseline fixtures will be limited to 10% of the total fixture count per facility.** If, for example, more than 10% of the total number of fixtures is inoperative, the number of fixtures beyond 10% will be assumed to have a baseline fixture wattage of zero. Thus, the total baseline demand for the project will be adjusted accordingly.

#### *Usage Groups*

When performing the pre-installation activities associated with this M&V approach (discussed in the following section), Project Sponsors should organize the equipment into **usage groups**—collections of equipment with similar operating schedules and functional uses. For instance, although a site's open office lighting may have the same annual hours of operation as the private office lighting, the two have different functional uses. In this case, a change in the operating hours of the private office lights due to the installation of an occupancy sensor would not be relevant to the operating hours of the open office lights. Therefore, private offices and open office areas should be assigned to separate usage groups. Refer to Table 2.3 for the recommended minimum number of usage groups for different types of sites.

**Table 2.3: Suggested minimum numbers of usage groups for project site types**

Building Type	Minimum Number of Usage Groups	Common Usage Groups
Office Buildings	6	General offices, private offices, hallways, restrooms, conference, lobbies, 24-hr
Education (K-12)	6	Classrooms, offices, hallways, restrooms, admin, auditorium, gymnasium, 24-hr
Education (College/University)	6	Classrooms, offices, hallways, restrooms, admin, auditorium, library, dormitory, 24-hr
Hospitals/ Health Care Facilities	8	Patient rooms, operating rooms, nurses station, exam rooms, labs, offices, hallways
Retail Stores	5	Sales floor, storeroom, displays, private office, 24-hr
Industrial/ Manufacturing	6	Manufacturing, warehouse, shipping, offices, shops, 24-hr
Other	10	Function or Usage/Characteristics

*Metering Requirements*

For facilities with little variation in weekly operating schedules (such as offices), monitoring should be conducted for each selected circuit for a recommended minimum of **two to four weeks** during the entire year. Monitoring should not occur during significant holidays or vacations. If a holiday or vacation falls within the monitoring period, the duration should be extended for as many days as that holiday or vacation. For facilities such as schools, where operating hours vary seasonally, monitoring should be conducted for a minimum period during each season (i.e., in-session [fall], and out-of-session [summer]). Table 2.4 shows the required minimum number of circuits to randomly sample depending on usage group population; note that, because lighting loggers sometimes fail, over-sampling is strongly recommended.

**Table 2.4: Metering sample sizes\***

Population of Lines in Usage Group (n)	Sample Size
n<4	3
5≤n<8	5
9≤n<12	6
13≤n<20	7
21≤n<70	8
71≤n<300	10
n>300	11

\* Sample sizes assume a confidence interval of 80%, precision of 20%, and a coefficient of variation (cv) of 0.5 for the population indicated.

As part of the Final Application M&V plan, the Sponsor should specify the meter to be used on a site-specific basis. The light loggers employed should minimally record date and time and indicate fixture operation in a downloadable electronic format.

#### **2.3.1.2 Pre-Installation Inspection**

CenterPoint Energy or its contractor will conduct a pre-installation inspection to verify that the Sponsor has properly documented the baseline. The criterion for baseline acceptance is that the installed demand of the sample must be within  $\pm 5\%$  of the demand reported on the lighting survey form. If significant errors are found, the Sponsor is allowed to resubmit corrected lighting tables. If the project fails inspection twice due to incorrect survey forms, the Project Sponsor will bear the cost of subsequent inspections.

#### **2.3.1.3 Monitoring of Pre-Installation Hours**

For fixtures that will have controls installed, the Project Sponsor must monitor the pre-installation operating hours of those lighting fixtures. For usage groups without controls, the pre-installation operating hours will be assumed equal to the monitored post-installation operating hours. These hours are determined by monitoring a statistically significant sample of fixtures in each usage group.

### **2.3.2 Post-Installation M&V Activities**

#### **2.3.2.1 Post-Installation Equipment Survey**

The Sponsor is required to conduct a post-installation lighting equipment survey as part of the IR. The purpose of the post-installation equipment survey is to inventory the actual installed replacement equipment. Fixture wattages should be based on the Table of Standard Fixture Wattages. In the IR, the proposed equipment information listed in the approved FA should be updated to reflect the actual, post-retrofit conditions and equipment found during the survey after installation. Any equipment listed in the approved FA that was not in fact replaced should remain in the lighting equipment inventory – in this case, simply copy the pre-retrofit information to the post-retrofit columns.

#### **2.3.2.2 Post-Installation Inspection**

CenterPoint Energy or its contractor will conduct a post-installation inspection to verify that the retrofit was installed as reported. In most cases, CenterPoint Energy or its contractor will inspect statistically significant samples taken from the entire lighting population. The criterion for acceptance is that the installed demand of the sample must be within  $\pm 5\%$  of the demand submitted on the post-installation survey form. If significant errors are found that cause the error to be greater than 5%, CenterPoint Energy will inform the Sponsor that the submitted lighting survey table must be corrected and resubmitted, citing the major cause of the errors found.

#### **2.3.2.3 Post-Installation Operating Hours**

The Project Sponsor should determine the post-installation operating hours by monitoring a statistically significant sample of fixtures listed in the equipment inventory. The Project Sponsor should develop a sampling plan to monitor the average operating hours of a sample of fixtures in each usage group, both with and without controls. The required usage group sampling sizes and metering requirements, and equations for calculating average operating hours (**Error! Reference source not found.**) and CF (**Error! Reference source not found.**), are defined under *Metering Requirements* in Section **Error! Reference source not found.**

### 2.3.3 Calculation of Demand and Energy Savings

The pre- and post-installation operation hours are calculated according to Equations 2.7 through 2.10 below. Peak demand savings, and energy savings are calculated according to Equations 2.11 through 2.16 below. The hours of operation should be calculated for each usage group and for each season that the operating hours may vary (as with schools). For each usage group, the annual hours of operation are determined by averaging all the seasonal hours of operation for that usage group. Interactive HVAC demand and energy savings may be calculated *only* for lighting retrofits taking place in conditioned spaces. Lighting retrofits in unconditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments.

#### 2.3.3.1 Pre-Installation Hours of Operation (Usage Groups with Controls)

Equation 2.7:

$$\text{Average Pre-Seasonal Operating Hours [hrs]} = \frac{\text{Pre-Hours Lights On}}{\text{Pre-Hours Lights Metered}} * \text{Hours in Season}$$

Equation 2.8:

$$\text{Pre-Annual Hours Operating Hours [hrs]} = \text{Sum of } \{ \text{Average Pre-Seasonal operating hours [hrs]} \}$$

#### 2.3.3.2 Post-Installation Hours of Operation (All Usage Groups)

Equation 2.9:

$$\text{Average Post-Seasonal Operating Hours [hrs]} = \frac{\text{Post-Hours Lights On}}{\text{Post-Hours Lights Metered}} * \text{Hours in Season}$$

Equation 2.10:

$$\text{Post-Annual Hours of Operation [hrs]} = \text{Sum of } \{ \text{Average Post-Seasonal operating hours [hrs]} \}$$

#### 2.3.3.3 Peak Demand Savings

Equation 2.11:

$$\text{Connected Lighting Load Reduction [kW]} = \text{Pre Lighting Demand [kW]} - \text{Post Lighting Demand [kW]}$$

Equation 2.12:

$$\text{Interactive HVAC Demand Savings [kW]} = \text{Connected Lighting Load Reduction [kW]} * 0.10$$

Equation 2.13: (See Error! Reference source not found. for Coincidence Factor calculation)

$$\text{Total Demand Savings [kW]} = (\text{Connected Lighting Load Reduction [kW]} + \text{Interactive HVAC Demand Savings [kW]}) * \text{Coincidence Factor}$$

**2.3.3.4 Energy Savings**

Equation 2.14:

$$\text{Lighting Energy Savings [kWh]} = \{ \text{Pre Lighting Demand [kW]} * \text{Pre Annual Operating Hours} \} - \{ \text{Post Lighting Demand [kW]} * \text{Post Annual Operating Hours} \}$$

Equation 2.15:

$$\text{Interactive HVAC Energy Savings [kWh]} = \text{Lighting Energy Savings [kWh]} * 0.05$$

Equation 2.16:

$$\text{Total Energy Savings [kWh]} = \text{Lighting Energy Savings [kWh]} + \text{Interactive HVAC Energy Savings [kWh]}$$

**Example**

A lighting efficiency and controls project is proposed for a small office building. Controls are to be installed in some common offices, private offices, and restrooms. The Project Sponsor submits a lighting survey detailing the existing and proposed equipment inventory. The following table summarizes the existing and proposed connected lighting load (including Coincidence Factors) and operating hours for each usage group in the project.

Usage Group	# of Survey Lines	Connected Lighting Load (kW)		Sample Size <sup>2</sup>	CF	Control Measure	Pre-Installation			Post-Installation		
		Existing	Proposed				On	Meter	Season	On	Meter	Season
Common Offices	45	50.5	20.5	9	82%		-	-	8760	450	504	8760
Common Offices w/controls	20	45	21.5	7	75%	Daylight Control	450	504	8760	202	504	8760
Private Offices	20	26	10.5	7	78%		-	-	8760	227	504	8760
Private Offices w/controls	10	21.5	10	6	54%	Occ. Sensor	300	504	8760	205	504	8760
Conf. Rooms	20	19.5	7.5	7	54%		-	-	8760	159	504	8760
Misc. Facilities	30	8.5	4	8	72%		-	-	8760	147	504	8760
Continuous	25	6	2.5	4	100%		-	-	8760	501	504	8760
Restrooms	10	1.5	0.5	3	95%		-	-	8760	135	504	8760
Restroom w/controls	10	3.5	1.5	6	66%	Occ. Sensor	480	504	8760	157	504	8760

<sup>2</sup> For this example, the sample sizes are reduced for certain usage areas below that indicated by the statistical accuracy requirements due to the small amount of savings in certain groups (e.g. restrooms) or the confidence in the estimated operating hours (continuous areas).

In this example, the operating hours are metered according to the required sample size for each usage group in the project. All fixtures have only one operating season; therefore, the light loggers are installed for one three-week pre-installation period (usage groups with controls only), and one three-week post-installation period (all usage groups). The operating hours for each usage group are the average of observed operating hours from all meters. The CF values were determined using **Equation 1.8**.

Using equations (a) through (h), the energy savings for *Common Offices with Controls* will be

$$(a) \text{ Pre - Annual Operating Hours [hrs]} = \left\{ \left[ \frac{450}{504} \right] * 8,760 \right\} = 7,821 \text{ [hrs]}$$

$$(b) \text{ Post - Annual Operating Hours [hrs]} = \left\{ \left[ \frac{202}{504} \right] * 8,760 \right\} = 3,511 \text{ [hrs]}$$

$$(c) \text{ Connected Lighting Load Reduction [kW]} = 45.0 \text{ [kW]} - 21.5 \text{ [kW]} = 23.5 \text{ [kW]}$$

$$(d) \text{ Interactive HVAC Demand Savings [kW]} = 23.5 \text{ [kW]} * 0.10 = 2.4 \text{ [kW]}$$

$$(e) \text{ Total Demand Savings [kW]} = \{ 23.5 \text{ [kW]} + 2.4 \text{ [kW]} \} * 0.75 = 19.4 \text{ [kW]}$$

$$(f) \text{ Lighting Energy Savings [kWh]} = 45.0 \text{ [kW]} * 7,821 \text{ [hrs]} - 21.5 \text{ [kW]} * 3511 \text{ [hrs]} = 276,459 \text{ [kWh]}$$

$$(g) \text{ Interactive HVAC Energy Savings [kWh]} = 276,459 \text{ [kWh]} * 0.05 = 13,823 \text{ [kWh]}$$

$$(h) \text{ Total Energy Savings [kWh]} = 276,459 \text{ [kWh]} + 13,823 \text{ [kWh]} = 290,282 \text{ [kWh]}$$

The energy savings are then calculated for each usage group.

**Equation Solutions**

Usage Groups	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
Common Offices	-	7,821	30.0	3.0	27.1	234,630	11,732	246,362
<b>Common Offices w/Controls</b>	<b>7,821</b>	<b>3,511</b>	<b>23.5</b>	<b>2.4</b>	<b>19.4</b>	<b>276,459</b>	<b>13,823</b>	<b>290,282</b>
Private Offices	-	3,945	15.5	1.6	13.3	61,148	3,057	64,205
Private Offices w/Controls	5,214	3,563	11.5	1.2	6.9	76,471	3,824	80,295
Conference Rooms	-	2,764	12.0	1.2	7.1	33,168	1,658	34,826
Misc. Facilities	-	2,555	4.5	0.5	3.6	11,498	575	12,073
Continuous	-	8,708	3.5	0.4	3.9	30,478	1,524	32,002
Restrooms	-	2,346	1.0	0.1	1.0	2,346	117	2,463
Restrooms w/Controls	8,343	2,729	2.0	0.2	1.5	25,107	1,255	26,362
<b>Total</b>					<b>83.8</b>	<b>751,305</b>		<b>788,870</b>