Commercial and Industrial Lighting Controls Evaluation Protocol

Steve Carlson, DNV KEMA

The Commercial and Industrial Lighting Controls Evaluation Protocol (the protocol) describes methods to account for energy savings resulting from programmatic installation of lighting control equipment in large populations of these facilities:

- Commercial
- Industrial
- Government
- Institutional, and
- Other nonresidential facilities.

Historically, lighting control equipment has accounted for a relatively small portion of cost-effective, electric energy-efficiency resources in the United States. However, use of lighting controls has been increasing due to building efficiency certification standards (such as LEED) and the increased prevalence of demand-response programs.

This evaluation protocol, which focuses on lighting controls, is based on the assumption that the primary data captured will be used either to inform the evaluation or to determine deemed savings in a technical reference manual (TRM).

By following the methods presented here, evaluators can determine energy savings resulting from lighting controls installed through efficiency programs in a manner consistent across different jurisdictions or regions. The resulting data will provide planners, policy makers, regulators, and others with sound, comparable information for use in comprehensive energy planning.[1]

This protocol does not address savings resulting from changes in codes and standards, or from education and training activities.[2] When lighting controls are installed in conjunction with a lighting retrofit project, the lighting control savings must be calculated parametrically with the lighting retrofit project; so double counting of savings does not occur.[3]

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[1] As discussed under Section 7 of the Introduction chapter to the UMP Report, small utilities (as defined under the SBA regulations) may face additional constraints in undertaking this protocol. Therefore, alternative methodologies, such as those presented here, should be considered for such utilities.

[2] This protocol only addresses automated lighting control measures, which do not require behavioral actions by space occupants (such as “tuning” light levels for different tasks).

[3] Typically, post-lighting retrofit wattages are used to calculate the lighting controlled kW value for lighting control savings calculations.

1 Measure Description

An "energy-efficient measure" can be defined as a set of actions and equipment changes resulting in reduced energy use—as compared to standard or existing practices—that maintain the same or improved service levels for customers or processes. Lighting controls are an energy-efficient measure because, in addition to delivering the light levels required for activities or processes in facilities, they can: (1) shut off lighting fixtures when a space is unoccupied, and/or (2) operate lighting at reduced power when ambient light levels are high.

For retrofit installations, the baseline condition typically equals the lighting operating at normal power levels or when the space is both occupied and unoccupied during normal business hours.[4] For new construction, the baseline conditions are generally provided by state and local building codes. However, these codes, which vary widely throughout the country, typically require some form of control for most interior lighting. This document contains a detailed discussion of baselines.

Lighting control measures in commercial, industrial, and other nonresidential facilities include:

- Sweep controls/energy management systems that shut off lighting at a set time, typically after normal operating hours.
- Lighting occupancy sensors (OS) that turn lights on or off, based on space occupancy conditions.
- Dimming control systems:
- Stepped dimming systems, such as dual ballasts (inboard/outboard);
- Dual ballast high/low high-intensity discharge (HID);[5] and
- Continuous daylight dimming systems.

Typically, lighting controls do not provide a sufficiently large component of an energy-efficiency program to warrant their own evaluation efforts, so these measures tend to be included as small parts of commercial and industrial program evaluation. Thus, little effort has been expended to move beyond post-installation metering or applying a 30% control savings factor (CSF).[6]

4 In this case "normal" refers to fixtures operating at full power, and this standard is applicable for all forms of lighting control applications during business operating hours.

5 Such HID fixtures typically have only one lamp that can be operated at two output levels by a two stage ballast. This differs from stepped dimming systems that dim by controlling lamps powered by a single ballast.

2 Application Conditions of Protocol

This protocol applies to the installation in customer facilities of commercial, industrial, and nonresidential lighting control measures associated with energy-efficiency programs. While methods described in this protocol apply to all programs, the issues with customer and baseline equipment data vary with each.

Programs for commercial, industrial, and nonresidential lighting, which include lighting controls, can be classified as targeting either retrofit markets (serving existing facilities) or new construction markets. Various delivery methods are associated with these programs, and the method used depends on the target markets and customer types. The program delivery types described below apply to existing building programs.

The delivery method is typically distinguished by the party receiving incentive payments from a program. The most common program delivery types are: (1) incentive and rebate, and (2) direct install.

2.1 Incentive and Rebate

Under this delivery method, administrators pay program participants in target markets for installing lighting control measures. Participants receive an incentive payment that is based on either annual energy savings ($/kWh) for each installed measure or on demand savings ($/kW). Participants include design teams, contractors, building owners, or building managers.

The annual energy savings are estimated through one or both of these techniques:

- Simple engineering calculations
- A measurement-and-verification (M&V) process that measures key parameters such as equivalent full load hours (EFLH), controlled fixture wattages, or a CSF as part of project implementation.

Programs also may pay rebates for specific lighting control equipment types (for example, ceiling-mounted OS), with the program utilizing assumptions about replaced equipment. Thus, increased administrative efficiency is exchanged for less certainty about baseline conditions and, therefore, savings. Note that this type of program implementation approach is often referred to as "deemed" savings approach, where savings are developed on a per-unit basis, and very little site-specific information is required to determine the *ex ante* program savings estimate.

Incentive programs often collect more detailed baseline data than do rebate programs. This includes extensive data regarding controlled equipment wattages and hours of operation, which facilitates the determination of savings impacts (typically using a savings calculation based on these site-specific data). Although rebate programs typically begin with useful information regarding the quantity of lighting control equipment, these programs do not always collect data about controlled fixtures, because it is not necessary to calculate the *ex ante* program savings.

2.2 Direct Install

Using this delivery method, contractors engaged through a program receive payment from that program for installing lighting control equipment in customer facilities. The customers receive a lighting control measure for free or at a reduced cost. Direct-install programs target hard-to-reach customers—typically small businesses—who are often overlooked by contractors working through incentive and rebate programs. Direct-install programs typically do not focus on lighting controls, but these may be eligible measures.

2.3 New Construction Programs

New construction programs primarily employ incentives and rebates to achieve energy-efficiency reductions. However, these programs present evaluators with a dilemma in establishing baselines for buildings that previously did not exist.

This problem can be addressed by referring to new construction energy codes for commercial, industrial, and nonresidential facilities (usually by referencing ASHRAE Standard 90.1 or IECC). Section 9.4.1 of the ASHRAE Standard defines lighting controls that are mandatory for interior lighting in buildings larger than 5,000 ft^2.[7] There may be federal, state, and local standards that contain additional baseline constraints on lighting controls.

3 Savings Calculations

The project and program savings for lighting controls and other technologies result from the difference between retrofit use and use that *would have occurred* had the measure not been implemented (the baseline). The fundamental savings equation is this:

> Energy or Demand Savings = (Baseline Period Energy Use – Reporting-Period Energy Use) ± Adjustments

The equation's adjustment term calibrates baseline and/or reported use and demand to the same set of conditions. Adjustments are routinely made to account for changes in schedules, occupancy rates, weather, or other parameters that shift between baseline and reporting periods. While adjustments commonly are applied to HVAC measures, they are less commonly applied to lighting measures (or the adjustments are inherent in algorithms for calculating savings).

3.1 Algorithms

The following equations calculate primary energy savings for lighting control measures in commercial, industrial, and nonresidential facilities.

Equation 1: Lighting Control Electric Energy Savings

$$\text{kWh Save}_{lc} = \text{kW}_{controlled} * \text{EFLH}_{pre} * \text{CSF}$$

where:

kWh Save_{lc} = Annual kWh savings resulting from the lighting control project

$\text{kW}_{controlled}$ = Sum (Fixture Wattage * Quantity Fixtures) for controlled fixtures

EFLH_{pre} = Annual equivalent full load hours prior to application of controls

7 ASHRAE 90.1, 2004, page 61 addresses mandatory provisions and exceptions for lighting controls in new constructed buildings.

CSF = Control Savings Factor is the annualized reduction factor calculated across the EFLH

Equation 2A: Lighting Control Savings Factor

$$CSF = 1 - (EFLH_{post} / EFLH_{pre})$$

where:

CSF = Control savings factor is the annualized reduction factor calculated across the EFLH

$EFLH_{pre}$ = Annual equivalent full load hours before the application of controls

$EFLH_{post}$ = Annual equivalent full load hours after the application of controls

When calculating the site level CSF using measured data for multiple control points, develop the weighted average by using the kW controlled as the weighting factor.

Equation 2: Interactive Cooling Electric Energy Savings

$$kWh_{interact - cool} = kW_{cool} \times IF_c \times Hours_{cool}$$

Equation 3: Interactive Heating Electric Energy Savings

$$kWh_{interact - heat} = kW_{heat} \times IF_h \times Hours_{heat}$$

where:

$kWh_{interact - cool}$ = Interactive cooling savings due to the lighting control project

kW_{cool} = Mean kW reduction coincident with the cooling hours

$Hours_{cool}$ = Hours when the space is in cooling mode

IF_c = Interactive cooling factor, ratio of cooling energy reduction per unit of lighting energy; due to reductions in lighting waste heat removed by a HVAC system

$kWh_{interact - heat}$ = Interactive heating savings due to lighting control project (which is a negative value)

kW_{heat} = Mean kW reduction coincident with the heating hours

$Hours_{heat}$ = Hours when the space is in heating mode

IF_h = Interactive heating factor, ratio of heating energy increase per unit of lighting energy; due to reductions in lighting heat removed by a HVAC system

Equation 4: Total annual energy savings

$$\text{kWh Save}_{total} = \text{kW Save}_{lc} + \text{kWh}_{interact - cool} + \text{kWh}_{interact - heat}$$

3.1.1 Role of the Lighting Control Program Implementer

Successful application of the protocol requires collecting standard data in a prescribed format, as part of the implementation process. The protocol also requires tracking project savings and program savings that are estimated on the basis of the standard data.

The implementer is responsible for ensuring collection of data required to track program activity and to calculate savings at the project level. The implementer also is responsible for maintaining a program activity record, including anticipated savings by project.

3.1.2 Implementation Data Requirements

For all projects, this protocol recommends that the program implementer collect and archive the data needed to execute the savings algorithms. These data are:

- Controlled fixture inventory, including fixture wattage;
- Controlled fixture quantities;
- Controlled fixture baseline lighting EFLH;
- CSF;
- Usage group assignments;
- Heating and cooling equipment types;
- Interactive factor for cooling (optional); and
- Interactive factor for heating (optional).

Facilities (or spaces within facilities where the project has been installed) are classified as cooled/uncooled and heated/unheated. It is important to record information about heating and cooling equipment and the fuel types for each facility or space because this information is required to estimate interactive effects.

3.2 Implementation Data Collection Method

The protocol recommends participants collect and submit the required data as a condition for program enrollment. The protocol also recommends the implementer specify the formats for data reporting, either by supplying a structured form (such as a spreadsheet) or by specifying data fields and types used when submitting material to the program.

The format must be electronic, searchable, and sortable, and it must support combining multiple files into single tables for analysis by the implementer. Although faxes, PDFs, and JPEG formats do not meet these criteria, Microsoft Excel and comma-separated text files are acceptable formats.

The data reporting format should be structured to allow verification of project installations. Each record or line in the report represents a collection of identical fixture types that are:

- Installed in an easily located room, floor, or space, and
- Belong to one usage group.

Table 1 lists fields required in the data reporting format.[8]

Table 1: Required Lighting Control Data Fields

Field	Note
Location	Floor number, room number and other descriptions
Usage group	
Location cooling	Yes/no
Conditioned floor area	Square footage of conditioned space
Location cooling type	Water cooled chiller, air cooled chiller, packaged DX, etc.
Location cooling fuel	Electric, non-electric
Location heating	Yes/no
Location heating type	Boiler steam/hydronic, heat pump, forced air, strip heat, etc.
Location heating fuel	Electric, non-electric
Controlled fixture type	From lookup table supplied by implementer, manufacturers cut sheet
Controlled fixture count	
Controlled fixture wattage	From lookup table supplied by implementer, manufacturers cut sheet
Pre-control EFLH	Requirement for pre-metering depends on control type
Control Savings Factor	Will be calculated using pre/post or post only data
IF_c	Interactive factor for cooling, from lookup table, optional
IF_h	Interactive factor for heating, from lookup table, optional
kWhsave	Will be calculated using pre/post or post only data
Measure Cost	Cost of measure in dollars
Incentive Cost	Cost of incentive in dollars

For each project, lighting contractors or other program participants should record:

- Types, quantities, and wattages of all lamps, ballasts and fixture types controlled by a lighting control measure; and
- All lighting control equipment types and locations throughout the facility.
- For lighting control measures that reduce the power outputs of fixtures, describe the dimming controls, so each increment of light reduction has an appropriate kW value established.
- For daylight dimming systems, identify the locations and specify the minimum power levels of ambient light sensors. This will enable modeling of the system using building simulation software, if necessary. (Sensor location is not required when using a spreadsheet savings estimation approach.)

[8] The data sources for these fields are described in Section 5.4, Data Requirements and Sources, of this protocol

The protocol recommends integrating savings verification into the program administrative process, particularly regarding data tracking. Impact evaluations of lighting efficiency and lighting control programs remain highly dependent on data developed in conjunction with the lighting retrofit construction process. These data should be collected and reported by the project contractor.

To verify the accuracy of data provided on the lighting inventory forms, the administrator should employ a third-party expert to conduct periodic, systematic reviews and inspections of a sample of completed projects. Initially, the sampling procedure should be implemented randomly on a fixed-percentage basis (approximately 10%). This will ensure the contractor cannot predict projects to be inspected.

In addition to requiring the contractor to correct discrepancies, the administrator may choose to impose penalties for egregious or repeated errors. Once a contractor has proven reliable, the sampling percentage can be reduced, but the random sampling procedure should be maintained.

4 The Role of the Evaluator

The evaluator's role is to determine the energy savings resulting from lighting control efficiency programs. The procedure entails these steps:

1. Reviewing a sample of completed projects, which may require conducting on-site M&V activities,
2. Calculating a realization rate (the ratio of evaluator to implementer anticipated savings), and
3. Using the realization rate to adjust implementer-anticipated savings.

4.1 Evaluator Data Requirements

This protocol recommends that both the program evaluator and the implementer collect the same data. As described in the Measurement and Verification Plan section, the evaluator must have access to the implementation lighting inventory forms and participant application materials for each project in the sample.

4.2 Evaluator Data Collection Method

Under the protocol, the implementer provides the evaluator with a copy of the program and project data tracking record for the evaluation review period. (This record contains the fields shown in Table 1.) The implementer also provides all records for projects in the evaluation review sample, including application materials and site contact information.

The protocol recommends the evaluator collect additional M&V data during site visits conducted for the sample of evaluation review projects. Table 2 lists data required for each project in the evaluation sample.

Table 2: Lighting Control Data Required by Evaluator

Field	Note
Location	From Implementer
Usage group	From Implementer
Location cooling	From Implementer, verified by evaluator
Location cooling type	From Implementer, verified by evaluator
Location cooling fuel	From Implementer, verified by evaluator
Location heating	From Implementer, verified by evaluator
Location heating type	From Implementer, verified by evaluator
Location heating fuel	From Implementer, verified by evaluator
Controlled fixture type	From Implementer, verified by evaluator
Controlled fixture count	From Implementer, verified by evaluator
Controlled fixture wattage	From Implementer, verified by evaluator
Pre-control EFLH	From Implementer, could be measured by evaluator
CSF	Measured by evaluator
IF_c	Interactive factor for cooling, from lookup table, optional
IF_h	Interactive factor for heating, from lookup table, optional
kWh_{save}	Will be calculated using pre/post or post only data

5 Measurement and Verification Plan

The evaluator is responsible for meeting M&V requirements in the protocol, so the M&V plan describes how evaluators determine verified energy savings in a facility where a lighting controls efficiency project has been installed. All M&V activities in the protocol are conducted for a representative sample of completed projects. To determine program savings, the M&V results are applied to the population of all completed projects.

5.1 IPMVP Option

The selection of the appropriate International Performance Measurement and Verification Protocol (IPMVP)[9] evaluation method for reporting evaluated (*ex post*) savings is contingent upon site specific criteria. The key factors for determining the method are these:

- Availability of whole-premise, interval-metered data and, ideally, sub-metered lighting data, and
- The relative size of the savings impact attributable to the lighting control measure.

When the savings impact for the lighting control measure is at least 5% (and preferably at least 10% of the energy usage for the available interval data), then use IPMVP Option C – Whole

9 The IPMVP is considered the gold standard for evaluating energy-efficiency programs.

facility.[10] Option C requires that both pre- and post-metered data are available to evaluate the lighting control impacts. Since lighting controls often don't meet the relative impact criteria, IPMVP Option A (Retrofit Isolation: Key Parameter Measurement) approach is the most common method for evaluating *ex post* savings. The key parameters to be measured are $EFLH_{pre}$ and $EFLH_{post}$ for calculating the CSF term in Equation 1. Accurately measuring these variables typically requires determining lighting usage in the pre-control state (and measuring usage in the post-control state may also be required[11]).

Table 3 lists the metering requirements for measuring various types of lighting control measures. Table 3: Metering Requirements for Various Lighting Control Strategies

Lighting Control Measure	Metering Requirements		Metering Type
	Pre-Installation	Post-Installation	
Lighting Sweep Controls/EMS/Time Clock	Yes	Yes	Event or Power Logger
Occupancy Sensors	Yes	Yes/No	Event/Event &Occupancy Logger
Stepped Dimming (Dual Ballasts)	No	Yes	Event Logger
Dual Ballast (Hi/Low HID)	No	Yes	Power Logger
Continuous Daylight Dimming	No	Yes	Power Logger

In summary:

- Lighting sweep controls, EMS, and time clock measures require pre- and post-installation metering to establish EFLH and CSF accurately.
- Occupancy sensor measures can be determined effectively through pre-installation metering only if using a lighting event logger with infrared occupancy sensor capabilities.[12]
- Most dimming applications can be measured using post-installation data, but only when these are sufficiently accurate to support the assumption that uncontrolled kW would equal controlled lighting operating at full power.

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10 In this case, the data could be either whole-premise data or lighting end-use data, which contains the savings attributable to the lighting control measure/s as a portion of the data. In either case, the savings impact must be at least 5% of the total usage observed in the data in order to quantify the impacts accurately using this method.

11 IPMVP Option A retrofit isolation requires the key savings variable be measured pre and post. However, when conducting M&V in an impact evaluation, obtaining baseline data can be challenging because the program administrator often does not collect the data, and the evaluators commonly do not become involved until after the project is installed.

12 These loggers monitor lighting on/off as well as whether the space is occupied or unoccupied. These data, coupled with the lighting latency factor, can be used to establish EFLH and CSF. Some companies maintain these data by building type and space, offering data that can be purchased: www.sensorswitch.com/Literature.aspx#

- Event loggers typically are lighting loggers that monitor lighting on/off operations via a photocell; power loggers monitor power consumption of controlled lighting circuits.

Additionally, ASHRAE recommends that lighting levels be measured for lighting control measures—particularly dimming measures—to ensure that adequate lighting levels are maintained in the work area.

5.2 Verification Process

Verification involves visual inspections and engineering calculations to establish an energy-efficiency project's potential to achieve savings. The verification process determines the controlled fixture wattage and controlled fixture quantity parameters used to calculate the $kW_{controlled}$ variable in Equation 1. These are the steps for this process:

1. Select a representative sample of projects for review. (See the Sample Design chapter for guidance on sampling.)
2. Schedule a site visit with a facility representative for each project in the sample.
3. Conduct an on-site review for each project. This entails inspecting a representative sample of controlled lighting fixtures and lighting controls—reported by the implementer—to verify the controls are operating as reported. (See the Sample Design chapter for guidance on sampling.)
    a. Confirm or correct the reported controlled fixture types and wattages for each fixture in the sample.
    b. Confirm or correct reported quantities for all controlled fixtures in the sample.
    c. Confirm or correct the heating/cooling status and associated equipment for spaces in the sample.
    d. Interview facility representatives to check baseline fixture control types and quantities reported for the sample. Confirmation or correction will be based on the interviews. When available, use physical evidence to supplement the interviews. (This evidence may be lighting controls installed on fixture types or in areas not changed by the project.)
4. Use the findings from the on-site review to update the lighting control inventory form for the sample.

After completing of the verification process, the evaluator will have confirmed or corrected the fixture wattage and fixture quantity parameters used to calculate the $kW_{controlled}$ variable in Equation 1.

5.3 Measurement Process

Lighting control measures can be particularly challenging to measure, as they may require use of pre/post metering of either on/off operations or interval power consumption. The measurement process involves using electronic metering equipment to collect data for determining EFLH and CSF parameters in Equation 1. Usually, the metering equipment is installed temporarily during the measurement period. However, in some facilities, the data from existing BAS systems monitoring lighting circuits may be employed.

Meters and metering data used to measure lighting control operating characteristics either record a change of state (light on, light off), or the meters continuously sample and record current or power from a lighting circuit or the reduced light output of a fixture. All data must be time-stamped for application in the protocol.

5.3.1 About Data Loggers

Temporary metering equipment, in the form of data loggers, is most commonly used for establishing lighting EFLH.

Change-of-state (event) lighting data loggers are small (matchbox-sized), integrated devices consisting of a photocell, a microprocessor, and memory storage. These data loggers are mounted inside of fixtures. Each time the lamps in a fixture are turned on or off, the event is recorded and time stamped. Such lighting loggers are only suitable for monitoring on/off lighting controls, such as OS, and lighting sweep controls/energy management systems. Event meters can also be used with stepped dimming systems, such as inboard/outboard configurations, where controlled lamps can be isolated from uncontrolled lamps.

For lighting control systems that offer varying lighting power (such as dimming systems or dual ballast HID systems, where the lamps cannot be isolated), the interval power of the lighting system must be monitored.

Data loggers that are continuously sampling and recording information about lighting operating hours usually require an external sensor, such as a current transformer (CT) or photocell. Data loggers with CTs can monitor amperage to a lighting circuit. Spot measurements of the circuit's amperage with lights on and off establish the threshold amperages for "on" conditions.

Similarly, data loggers with an external photocell can record light levels in a space. Spot measurements of lumen levels with the fixtures on and off establishe the light level thresholds for "on" conditions. Data loggers are commonly used for amperage measurement; however, continuous light-level monitoring to determine hours of operation is less common.

Data logger failures due to incorrect adjustments, incorrect locations, or software launches occur commonly. This protocol recommends following manufacturer's recommendations carefully.

5.3.2 About the Measurement Process

Measurement involves metering lighting operating hours for a representative sample of controlled fixtures selected for verification. Meters are deployed—or, if using an existing building management system BMS, metering routines are established―during the verification site visit. These are the activities for this process.

5.3.2.1 Meter operating hours for each circuit in the verification sample.

- If using light loggers, deploy loggers in one or more fixtures controlled by the circuit. Only one logger per last point of control is required; however, additional loggers are commonly deployed to offset logger failure or loss.
- If measuring amperage, install the CT and data logger in lighting panels for the sampled circuit. The sampling interval should be 15 minutes or less. Spot-measure

amperage with lights on and off for the circuit leg with CT. Record the amperage threshold for the lights-on condition.

- If the measure is an on/off type of lighting control (such as occupancy sensors) then use an event-type power logger. (These power loggers, which record a change of state when the power is on and off, provides similar data as change-of-state lighting loggers.) The sampling interval is irrelevant for an event logger since it captures transitions, so the data can be output at any interval desired.
- If using BMS, establish trends for lighting on/off status for each circuit in the sample. The sampling interval should be 15 minutes or less. Check that BMS has sufficient capacity to archive recorded data. Also, confirm that the metering task will not adversely slow the BMS response time.

5.3.2.2 Check data logger operations.
Before leaving the site, spot-check a few data loggers to confirm they are recording data as expected. Correct any deficiencies and, if the deficiencies appear systemic, redeploy the loggers. If using BMS trends, spot-check the recorded data.

5.3.2.3 Leave metering equipment for the monitoring period.
The protocol recommends a monitoring period capturing the full range of facility operating schedules, so the metering period may include pre and post periods.

- For facilities with constant schedules (such as office buildings, grocery stores, and retail shops), the protocol calls for metering a minimum of two weeks for pre periods and a minimum of four weeks for post periods.
- Facilities with variable schedules require additional time, which is based upon the variability of the schedules and the length of time necessary to capture the periodicity of the schedule changes.
- Facilities with seasonal schedules, such as schools, should be monitored during active periods.

5.3.2.4 Analyze metering data.
Calculate the percentage of “on” time for metered lighting equipment for each usage group. When pre-control data are collected for control systems, pre-control EFLH can be calculated directly, and post EFLH can be calculated as well. In this case, the CSF equals 1 minus the ratio of post EFLH, divided by pre EFLH.

For lighting control measures varying seasonally, such as continuous daylight dimming systems, it is necessary to annualize metered data to account for daylight hours during the metering period. This ensures that summer metering does not over-predict savings and winter metering does not under-predict savings. Similarly, facilities with seasonal schedules (such as schools, which should be metered during active periods) have annual EFLH and CSF values adjusted to reflect the operating schedules.

5.3.3 Report M&V Savings
Use the information collected during the M&V processes to calculate M&V project savings. These are the steps for this process:

1. Using results from the last step in the measurement process and the sample lighting inventory form from the verification process, update the inventory EFLH and CSF parameters. Then calculate M&V savings for the sample.
2. Calculate the project realization rate (which is the ratio of M&V savings to savings reported by the implementer for the sample).
3. Calculate project M&V savings (which is the product of the project realization rate and the project savings reported by the implementer).
4. Use site-level savings estimates to develop program-level results. Site-level savings estimates are weighted and expanded upon based on the sample design to develop program-level realization rates and statistical relative precision at the selected confidence interval.[13]

5.4 Data Requirements and Sources

This section addresses information on the fixture wattage, EFLH, and CSF parameters in the algorithm equations. Data requirements are described in these sections: Role of the Lighting Controls Program Implementer and Role of the Evaluator. Additional details are provided in the M&V Plan section.

5.4.1 Fixture Wattage

Wattage values are measured according to American National Standards Institute (ANSI) standards[14] by research facilities working on behalf of manufacturers and academic laboratories. This protocol recommends using of fixture wattage tables that are developed and maintained by existing energy-efficiency programs and associated regulatory agencies. The tables, which list all common fixture types, are typically updated as new fixtures and lighting technologies become available.

Wattage tables are used by implementers and evaluators. In the wattage table, each fixture and screw-in bulb is fully described and assigned a unique identifier.

- The *implementer* enters a fixture code into the lighting inventory form, which automatically performs a lookup function to enter the associated demand into the form.
- The *evaluator* verifies or corrects the fixture type for the evaluation sample in a copy of the implementer's inventory form, thus automatically updating lighting values.

[13] The confidence interval and testing criteria (one-tail vs. two-tail) can be different based upon jurisdictional requirements. For example PJM requires relative precision of demand impacts be calculated at 90% confidence using a one-tail test. However, ISO-NE requires relative precision of demand impacts be calculated at 80% confidence interval using a two-tail test. Both calculations provide the same result.

[14] The ANSI 82.2-2002 test protocol specifies ambient conditions for ballast/lamp combinations in luminaires. The test is conducted on an open, suspended fixture. Actual fixture wattages vary, depending on the installation (suspended, recessed) and housing type. The differences end to be small—less than 5% (see *DOE 1993 Advanced Lighting Guidelines*.)

The protocol recommends adopting a fixture wattage table used by an established and recognized lighting-efficiency program.

5.4.1.1 Examples of Resources

As of May 2012, the following sources serve as examples:

- *Massachusetts Technical Reference Manual 2011*, *Massachusetts Device Codes and Rated Lighting System Wattage Table*. Available from the Massachusetts Energy Efficiency Advisory Council: http://www.ma-eeac.org/index.htm. This is a slightly abbreviated and simplified table of common fixtures and their wattages.
- *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs 2010, Appendix C Standard Fixture Watts*. Available from the New York Department of Public Service: http://www3.dps.ny.gov/W/PSCWeb.nsf/All/06F2FEE55575BD8A852576E4006F9AF7?OpenDocument. This is a comprehensive (34 page) list used by NYSERDA since the late 1990s.
- *Database for Energy Efficiency Resources.* Available from the California Public Utilities Commission: http://www.deeresources.com/. An exhaustive list of all parameters driving energy use and savings for a lengthy list of measures. References California codes and weather zones.
- An excerpt from the New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs is included in the Appendix to this protocol as an example of a wattage table.

5.4.2 EFLH and CSF

EFLH and CSF greatly vary by application. To minimize uncertainty, the protocol requires *evaluators* do the following: (1) measure pre and/or post EFLH (depending on the control type, as listed in Table 3); and (2) calculate the CSF.

The following section describes data sources and methods used by *program implementers* to estimate EFLH and CSF parameters and reliably report project and program savings.

The protocol requires that program participants provide the following in their lighting inventory forms: (1) estimates of EFLH values by usage group, and (2) an estimate of CSF by control type. Note that the CSF estimate should *not* be based on the building schedule alone, although this may be used to inform the estimate.

The protocol recommends that participants—with guidance from the program implementer—develop EFLH and CSF values using one of the following sources:

- Lighting schedules in buildings with energy management systems or time clocks that control lighting equipment. To determine whether schedules are overridden, interview the building manager. When available, control schedules (or trend data) provide reliable estimates of true lighting operating hours.

- Interview with the building manager. Building managers are usually familiar with lighting schedules; however, they may not know how lighting is controlled, so they may not be a good source of estimates for CSF values.
- Tables containing EFLH and CSF values by building type (provided by the program implementer).
- Combinations of interviews and tables.

For calculating and reporting project savings, the protocol recommends requiring contractors for lighting-efficiency programs primarily use deemed EFLH-by-building-type values. Then, use 30% or less of the value for the CSF.

When EFLH values can be reliably estimated using site-specific data from an operating schedule organized by lighting control usage group, use these values to calculate the pre-control EFLH. If the CSF value can be reliably calculated based on the control description, a calculated value should be used *when* the value does not exceed 50% of the published value.

Update deemed pre-control EFLH and CSF tables according to a continuous revision schedule, so that lighting programs using results from logger studies conducted for impact evaluation studies have current information. Table 4 lists the lighting control savings factors that were developed from ASHRAE 90.1 power adjustment factors.

Table 4: Lighting Control Savings Factors by Control Type

Lighting Control Type	Control Savings Factor
Light switch	0
No Controls	0
Daylight controls (DC) – continuous dimming	0.3
DC – multiple-step dimming	0.2
DC – ON/OFF	0.1
Occupancy sensor (OS)	0.3
OS w/DC – continuous dimming	0.4
OS w/DC – multiple-step dimming	0.35
OS w/DC – ON/OFF	0.35

6 Other Evaluation Issues

6.1 New Construction

Lighting control savings for new construction projects can be difficult to calculate, as it can be difficult to monitor pre-controls conditions. In some cases, one may override the controls, as to meter non-control conditions. Overriding controls can also be utilized for retrofit and incentive programs, providing the site contact is cooperative, and the extra site visit is considered in evaluation planning.[15] When possible, EFLH and CSF can be measured using pre/post metering techniques.

6.2 Coincidence Factor

The following equation converts the change in a connected load to a demand reduction coincident with a facility's utility peak period:

Equation 3

$$kW_{reduction,\ coincident} = kW_{reduction} \text{ x } CF$$

where:

CF equals the percentage of the lighting load turned on during a utility peak period. (This varies with peak definition.)

IF and CF parameters in Equation 3, Equation 4, and Equation 5 can be: (1) determined by measurement, (2) developed from a study of measured data, or (3) deemed based on prior studies and computer simulations (which is the most typical option). References for IF and CF values are provided at the end of this document.

7 Program Evaluation Elements

Building a foundation for the successful evaluation of a commercial, industrial, and nonresidential lighting controls program begins in the program design phase. Administrators must set data requirements before a program's launch, so when data are ultimately reviewed through an impact evaluation, the information required to conduct the research will be available.

Administrators support future evaluations by ensuring the data required for an impact study have been collected, stored, and checked for quality. These data include measured and stipulated values, which are available from prior studies or equipment tests.

[15] New Construction baselines may irrelevant, as lighting controls have mandatory provisions in recent standards (such as AHSRAE Standard 90.1-2004) requiring some form of lighting controls. For programmatic savings, any controls much exceed minimum baseline controls.

8 References

EFLH, CF, IF values and individual fixture wattages can be found in the following references. (The Pennsylvania reference includes an extensive table of fixture wattages.)

American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) *ANSI/ASHRAE/IESNA Standard 90.1-2004 Energy Standard for Buildings Except low-Rise Residential Buildings.*

California Energy Commission and California Public Utilities Commission. 2008. *Database for Energy Efficient Resources (DEER)*. http://www.energy.ca.gov/deer/

Massachusetts Program Administrators. 2011. *Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures 2012 Program Year – Plan Version.* http://www.masssave.com/

TecMarket Works. 2010. *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs- Residential, Multi-Family and Commercial/Industrial Measures.* Prepared for the New York Public Service Commission. http://www3.dps.ny.gov/W/PSCWeb.nsf/All/

Vermont Energy Investment Corporation. 2010. *State of Ohio Energy Efficiency Technical Reference Manual*. Prepared for the Public Utilities Commission of Ohio.

Pennsylvania Public Utility Commission. 2011. *Technical Reference Manual, Appendix C*. http://www.puc.state.pa.us/electric/Act129/TRM.aspx

Federal Energy Management Program. 2008. *M&V Guidelines: Measurement and Verification for Federal Energy Projects Version 3.0.* http://www1.eere.energy.gov/femp/index.html