NATIONAL RENEWABLE ENERGY LABORATORY

Chapter 2: Commercial and Industrial Lighting Evaluation Protocol

The Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures

Created as part of subcontract with period of performance September 2011 – September 2016

This version supersedes the version originally published in April 2013. The content in this version has been updated.

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Preface

This document was developed for the U.S. Department of Energy Uniform Methods Project (UMP). The UMP provides model protocols for determining energy and demand savings that result from specific energy-efficiency measures implemented through state and utility programs. In most cases, the measure protocols are based on a particular option identified by the International Performance Verification and Measurement Protocol; however, this work provides a more detailed approach to implementing that option. Each chapter is written by technical experts in collaboration with their peers, reviewed by industry experts, and subject to public review and comment. The protocols are updated on an as-needed basis.

The UMP protocols can be used by utilities, program administrators, public utility commissions, evaluators, and other stakeholders for both program planning and evaluation.

To learn more about the UMP, visit the website, https://energy.gov/eere/about-us/ump-home, or download the UMP introduction document at http://www.nrel.gov/docs/fy17osti/68557.pdf.

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Acronyms

CF	coincidence factor
COP	coefficient of performance
CT	current transformer
DOE	U.S. Department of Energy
HGSF	heat gain space fraction
HID	high-intensity discharge
HOU	hours of use
HVAC	heating, ventilating, and air conditioning
ISR	in-service rate
kW	kilowatt
kWh	kilowatt-hour
LED	light-emitting diode
LPD	lighting power density
M&V	measurement and verification
PCF	peak coincidence factor
UMP	Uniform Methods Project
W	watt

Protocol Updates

The original version of this protocol was published in April 2013.

This chapter has been updated to incorporate the following revisions:

- Added new section for midstream programs.
- Provided additional detail on the recommended duration of metering.
- Changed the recommended minimum metering time from two weeks to four weeks.
- Added an alternative approach to estimating interactive effects through the use of an engineering equation (in addition to the current approach that uses stipulated factors).
- Provided guidance for creating fixture codes for light-emitting diode fixtures not currently found in most look-up tables.
- Updated the protocol on reporting uncertainty based on new material from the International Performance Measurement and Verification Protocol.
- Applied the controls requirements of International Energy Conservation Code 2012 / 90.1-2010 to estimate of baseline hours of use for new construction projects.

Table of Contents

List of Figures

List of Tables

1 Measure Description

The Commercial and Industrial Lighting Evaluation Protocol (the protocol) describes methods to account for gross energy savings resulting from the programmatic installation of efficient lighting equipment in large populations of commercial, industrial, and other nonresidential facilities. This protocol does not address savings resulting from changes in codes and standards, or from education and training activities. A separate Uniform Methods Project (UMP) protocol, *Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol*, addresses methods for evaluating savings resulting from lighting control measures such as adding time clocks, tuning energy management system commands, and adding occupancy sensors.

Historically, lighting equipment has accounted for a significant portion of cost-effective, electric energy efficiency resources in the United States, a trend likely to continue as old technologies improve and new ones emerge. By following the methods presented here, the energy savings from lighting efficiency programs in different jurisdictions or regions can be measured uniformly, providing planners, policymakers, regulators, and others with sound, comparable data for comprehensive energy planning. Also, the methods here can be scaled to match the evaluation costs to the value of the resulting information.[1]

An energy efficiency measure is defined as a set of actions and equipment changes that result in reduced energy use—compared to standard or existing practices—while maintaining the same or improved service levels for customers or processes. Energy-efficient lighting measures in existing facilities deliver the light levels (illuminance and spatial distribution) required for activities or processes at reduced energy use, compared to original or baseline conditions. In new construction, “original or baseline condition” usually refers to the building codes and standards in place at the time of construction.

Examples of energy-efficient lighting measures in commercial, industrial, and other nonresidential facilities include:

- Retrofitting existing, linear, fluorescent fixtures with efficacious[2] lamps and ballasts, or delamping over-lit spaces
- Replacing compact fluorescent lamps with screw-in light-emitting diodes (LED) lamps
- Replacing metal halide high-bay fixtures with efficacious LED high-bay equipment.

In practice, lighting retrofit projects and new construction projects commonly implement lighting fixture and lighting controls measures concurrently. This protocol accommodates these mixed measures.

[1] As discussed in the “Considering Resource Constraints” section of the UMP *Chapter 1: Introduction*, small utilities (as defined under U.S. Small Business Administration regulations) may face additional constraints in undertaking this protocol. Therefore, alternative methodologies should be considered for such utilities.

[2] Efficiency of lighting equipment is expressed as “efficacy,” in units of lumens per Watt, where lumens are a measure of light output.

2 Application Conditions of the Protocol

Energy efficiency lighting programs result in the installation of commercial, industrial, and nonresidential high-efficiency lighting measures in customer facilities. The programs can take advantage of varying delivery mechanisms, depending on target markets and customer types. Primarily, these mechanisms can be distinguished by the parties receiving incentive payments from a program. Although the methods described in this protocol apply to all delivery mechanisms, issues verifying customer and baseline equipment data vary.

2.1 Common Program Types

The following are descriptions of common program types used to acquire lighting energy and demand savings.

2.1.1 Incentive and Rebate

Under this model, implementers pay program participants in target markets to install lighting measures. This type of program is generally referred to as a downstream program. A participant receives either an incentive payment, based on savings ($/kilowatt-hour [kWh]), or a rebate for each fixture or lamp ($/fixture, $/lamp). The terms incentive and rebate sometimes are used interchangeably, but generally, incentives are calculated based on project savings and rebates are based on equipment installed. Examples of participants include contractors, building owners, and property managers.

Savings can be estimated using simple engineering calculations. Some programs include a measurement and verification (M&V) process, in which key parameters—such as hours of use (HOU), baseline, and retrofit fixture wattages—are verified or measured, or both, as part of project implementation.

Rebate programs typically pay for specific lighting equipment types (for example, a 4-foot, four-lamp, T5 electronic ballast fixture), often after they have been installed, so assumptions must be made about baseline or replaced equipment. The result is a tradeoff: increased administrative efficiency for less certainty about baseline conditions (and therefore, savings).

Incentive programs often collect more detailed baseline data than do rebate programs. Typically, these data include baseline and retrofit equipment wattages and HOUs, which facilitate determination of savings impacts.

Although rebate programs typically track useful information about replacement lighting equipment, they may not collect baseline data.

2.1.2 Upstream Buy-Down

In upstream buy-down scenarios, programs pay incentive dollars to one or more entities such as retail outlets, distributors, or manufacturers in the lighting equipment market distribution chain. The upstream approach has been widely used in the residential sector, particularly for compact fluorescent lamp (CFL) commercial and industrial lighting programs.

Upstream programs do not interact with the end-use customers purchasing energy-efficient equipment, making the determination of baseline conditions and installation rates more difficult than for incentive and rebate programs. Program planners, implementers, and evaluators estimate these parameters using regional bulk sales data, market research studies, assessments of current product standards and practices, and experience with other programs.

A subset of upstream programs is the midstream model where incentives are paid to distributors for sales of pre-approved qualified products. Purchasers are contractors and commercial, institutional and governmental accounts. Programs can leverage the relationship between distributor, purchaser, and end-user to require information about equipment sales and the end-use installation. Midstream lighting programs are increasingly included in ratepayer-funded energy efficiency portfolios.

2.1.3 Direct Install

Under this delivery approach, contractors, acting on a program's behalf, install energy-efficient lighting equipment in customer facilities. The programs pay contractors directly. Customers receive a lighting retrofit at reduced cost. Direct-install programs often target hard-to-reach customers—typically small businesses—that are overlooked by contractors working with incentive and rebate programs.

Direct-install programs can usually collect precise information about baseline and replacement equipment, and the program implementers may have reasonable estimates of annual operating hours. Data, when collected, can be used directly by impact evaluation researchers.

2.2 Program Target Markets

In addition to being distinguished by their delivery mechanisms, commercial, industrial, and non-residential lighting programs can be classified by targeting retrofits (serving existing facilities) and new construction markets. Program delivery types described above apply to retrofit programs. New construction programs also employ incentives and rebates (and customers may benefit from upstream buy-downs) to improve lighting energy efficiency.

New construction programs present evaluators with a dilemma in establishing baselines for buildings that have yet to be built. The problem is addressed by referring to new construction energy codes for commercial, industrial, and nonresidential facilities (usually by referencing International Energy Conservation Code or ASHRAE Standard 90.1). The codes define lighting efficiency, primarily in terms of lighting power density (lighting watts/ft^2), calculated using simple spreadsheets. Other federal, state, and local standards may set additional baseline constraints on lamps, ballasts, and fixture efficiency/efficacy.

3 Savings Calculations

Project and program savings for lighting and other technologies result from the difference between the energy consumption that would have occurred had the measure not been implemented (the baseline) and the consumption occurring after the retrofit. Energy calculations use the following fundamental equation:

Equation 1. Energy Savings = (Baseline-Period Energy Use – Reporting-Period Energy Use) ± Adjustments

The equation's adjustment term calibrates baseline or reporting use and demand to the same set of conditions. Common adjustments account for changes in schedules, occupancy rates, weather, or other parameters that can change between baseline and reporting periods. Adjustments commonly apply to heating, ventilating, and air conditioning (HVAC) measures, but less commonly to lighting measures, or are inherent in algorithms for calculating savings.

Regulators and program administrators may require that lighting energy efficiency programs report demand *and* energy savings. Demand calculations use the following fundamental equation:

Equation 2. Demand Savings = (Baseline-Period Demand – Reporting-Period Demand) ± Adjustments

Demand savings, which is calculated for one or more time-of-use periods, is typically reported for the peak period of the utility system serving the efficiency program customers.

3.1 Algorithms

The following equations calculate first-year energy and demand on-site savings for lighting measures in commercial, industrial, nonresidential facilities:

3.1.1 Energy Savings

Equations in this section are used to calculate first-year energy savings for lighting measures.

Equation 3. Lighting Electric Energy Savings

$$kWh\ Save_{light} = \left[\sum_{u,i}\left(\frac{fix\ watt_{base,i} \cdot qty_{base,i}}{1000} \cdot HOU_{base}\right)_u - \sum_{u,i}\left(\frac{fix\ watt_{energy\ efficient,i} \cdot qty_{ee,i}}{1000} \cdot HOU_{ee}\right)_u\right] \cdot ISR$$

Where:

$kWh\ Save_{light}$ = Annual kWh savings resulting from the lighting efficiency project

$fix\ watt_{base,\ energy\ efficient,\ i}$ = Fixture wattage, baseline or energy-efficient, fixture type i

$qty_{base, energy efficient, i}$ = Fixture quantity, baseline or energy-efficient, fixture type i

u = Usage group, a collection of fixtures sharing the same operating hours and schedules, for example all fixtures in office spaces or hallways

$HOU_{base, energy efficient}$ = Annual hours of use, baseline or energy-efficient, usually assumed unchanged from baseline unless new controls are installed

ISR = In-service rate, the percentage of incentivized lamps or fixtures that are installed and operating. Applies to upstream buy-down programs, normally not applicable for incentive and rebate programs

Equation 4. Interactive Cooling Energy Savings for Interior Lighting

$$kWh\ Save_{interact-cool} = \frac{HGSF \cdot kW\ Save_{light} \cdot HOU_{cool}}{COP_{cool}}$$

OR

$$kWh\ Save_{interact-cool} = kWh\ Save_{light} \cdot IF_{kWh,cool}$$

Equation 5. Interactive Heating Energy Penalty for Interior Lighting

$$kWh\ Save_{interact-heat} = \frac{-HGSF \cdot kW\ Save_{light} \cdot HOU_{heat}}{COP_{heat}}$$

OR

$$kWh\ Save_{interact-heat} = kWh\ Save_{light} \cdot IF_{kWh,heat}$$

Where:

$kWh\ Save_{interact-cool}$ = Interactive cooling energy impact due to a lighting efficiency project

$kWh\ Save_{interact-heat}$ = Interactive heating energy impact from a lighting efficiency project

$kW\ Save_{light}$ = Connected kW savings ($kW_{base} – kW_{efficient}$) due to a lighting efficiency project

HOU_{cool} = Hours of use of lighting equipment coincident with cooling system operation

HOU_{heat} = Hours of use of lighting equipment coincident with heating system operation

$IF_{kWh, cool}$ = Interactive cooling factor: the ratio of cooling energy reduction per unit of lighting energy reduction

$IF_{kWh, heat}$ = Interactive heating factor: the ratio of heating energy increase per unit of lighting energy

COP_{cool} = Cooling system coefficient of performance

COP_{heat} = Heating system coefficient of performance

HGSF = Heat gain space fraction: the percent of lighting wattage that is transferred to the conditioned space as thermal energy.

The protocol provides two options each for calculating cooling and heating interactive effects: an engineering approach and a stipulated factor approach.

In the engineering approach, the HGSF represents the percentage of the lighting energy that is thermal energy added to the conditioned space. According to a 2007 ASHRAE study (Chantrasrisalai and Fisher 2007), the percentage of lighting energy transmitted to the space can range from 12% to 100% depending on the type of light fixture at typical operating conditions.[3] The protocol recommends a default of 70% to 80% HGSF. Calculating building-specific HGSF values is unusual due to the level of effort required.

Interactive effects apply only to interior lighting that operates in mechanically cooled or heated spaces.

Equation 6. Total Annual Energy Savings Due to Lighting Project

$$kWh\ Save_{total=}kWh\ Save_{light} + kWh\ Save_{interact-cool} + kWh\ Save_{interact-heat}$$

3.1.2 Electric Peak Demand Savings

The equations in this section are used to calculate first-year electric peak demand savings for lighting measures. Additional information is available in the Uniform Methods Project (UMP) *Chapter 10: Peak Demand and Time-Differentiated Energy Savings Cross-Cutting Protocol*.

Equation 7. Lighting Electric Peak Demand Savings

$$kW\ Peak\ Save_{light} = CF \cdot \sum_{u,i} \left(\frac{fix\ watt_{base,i} \cdot qty_{base,i}}{1000} - \frac{fix\ watt_{ee,i} \cdot qty_{ee,i}}{1000} \right)_u \cdot ISR$$

Where:

CF = coincidence factor, the fraction (0.0 to 1.0) of connected lighting load turned on during a utility peak period

[3] A value less than 100% means that a portion of the lighting energy is being transferred into the plenum rather than the conditioned space.

Equation 8. Interactive Electric Cooling Demand Savings for Interior Lighting

$$kW\ Peak\ Save_{interact-cool} = \frac{HGSF \cdot kW\ Peak\ Save_{light}}{COP_{cool}}$$

OR

$$kW\ Peak\ Save_{interact-cool} = kW\ Save_{light} \cdot IF_{kW,cool}$$

Where:

$kW\ Peak\ Save_{interact\text{-}cool}$ = Interactive electric cooling peak demand impact from a lighting efficiency project

HGSF = Heat Gain Space Fraction: the percent of lighting wattage that is transferred to the conditioned space as thermal energy

COP_{cool} = Cooling system coefficient of performance

$IF_{kW,\ cool}$ = Interactive cooling factor, ratio of cooling demand reduction per unit of lighting demand reduction during the peak period resulting from the reduction in lighting waste heat removed by an HVAC system

Interactive effects apply only to interior lighting operating in mechanically cooled spaces. Interactive heating effects are often ignored in North America because heating equipment is typically nonelectric and heating demand may not coincide with utility system peaks.

Equation 9. Total Electric Peak Demand Savings Due to Lighting Project

$$kW\ Peak\ Save_{total=}kW\ Peak\ Save_{light} + kW\ Peak\ Save_{interact-cool}$$

4 Role of the Lighting Program Implementer

Successful application of this protocol requires collecting standard data in a prescribed format as part of the implementation process. The protocol further requires tracking project and program savings estimated on the basis of those standard data.

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

4.1 Program Implementer Data Requirements

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

- Baseline fixture inventory, including fixture wattage
- Baseline fixture quantities
- Baseline lighting HOU
- Efficient fixture inventory, including wattage
- Efficient fixture quantities
- Efficient lighting HOU
- Usage group assignments
- Heating and cooling equipment types
- Interactive factor for cooling, or cooling equipment COP and lighting HOU coincident with cooling equipment operation (optional)
- Interactive factor for heating, or heating equipment COP and lighting HOU coincident with heating equipment operation (optional).

Facilities—or spaces within facilities where the project is installed—are classified as cooled/uncooled or heated/unheated. Recording information about heating and cooling equipment and fuel types for each facility or space allows for more precise estimation of interactive effects. Implementers may elect to use a program-level default values for the percent of space that is heated or cooled. The values can be based on earlier studies or evaluation reports for similar populations.

Note that some of the information will not be available for some program types (e.g., baseline fixture information for new construction, upstream, or midstream programs). See Section 8 for recommendations for midstream programs.

4.2 Implementation Data Collection Method

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

The format of the data must be electronic, searchable, and sortable. It must also support combining multiple files into single tables for analysis by the implementer. Microsoft Excel and comma-separated text files are acceptable formats; faxes, PDFs, and JPEGs are not.

The data reporting format should be structured to allow verification of the project installation. Each record or line in the report: (1) is a collection of identical fixture types, (2) is installed in an easily located room, floor, or space, and (3) belongs to one usage group. Table 1 lists the fields required in the data reporting format. All data are supplied by the participant or implementer.

Table 1. Required Lighting Data Form Fields

Field	Notes
Location	Floor number, room number, description
Usage group	
Location heating	Yes/no
Location heating type	Boiler steam/hydronic, rooftop gas-fired, etc.
Location heating fuel	Electric, natural gas, fuel oil, etc.
Location cooling	Yes/no
Location cooling type	Water cooled chiller, air cooled chiller, packaged DX, etc.
Location cooling fuel	Electric, natural gas, etc.
Baseline fixture type	From look-up table supplied by implementer, manufacturer cut sheet
Baseline fixture count	
Baseline fixture watt	From look-up table supplied by implementer, manufacturer cut sheet
Baseline HOU	From look-up table supplied by implementer, estimated by customer, bulk meter services or meter data
Efficient fixture type	From look-up table supplied by implementer, manufacturer cut sheet
Efficient fixture count	
Efficient fixture watt	From look-up table supplied by implementer, manufacturer cut sheet
Efficient lighting HOU	Same as baseline if no controls installed
IF_{cool}, or COP_{cool} and HOU_{cool}	Interactive factor for cooling from look-up table, or site-specific COP_{cool} and HOU_{cool} (optional)
IF_{heat}, or COP_{heat} and HOU_{heat}	Interactive factor for heating from look-up table, or site-specific COP_{heat} and HOU_{heat} (optional)
kWh_{save}	Calculated using savings algorithms
$kW\text{-}Peak_{save}$	Calculated using savings algorithms

The Appendix to this protocol contains an example of a lighting inventory form with the fields listed in Table 1.

Information at the usage-group level will typically not be available for midstream or upstream programs. Location-specific information such as cooling and heating type may also be unavailable. In such cases, program-level or building type-level defaults will be used by the implementer, and the evaluation may work to estimate and update these assumptions. See Section 8 for recommendations for the evaluation of midstream programs.

5 Role of the Evaluator

This section describes the evaluator’s role in determining gross energy savings due to participation in a lighting energy efficiency program. Gross savings result directly from program-related actions taken by participants in an energy efficiency program. A simple way of thinking about gross savings is that they can be observed at the customer utility meter, at least in theory. In practice, it is difficult to isolate program-induced changes from other simultaneous changes, or to attribute them solely to the program itself.

Gross savings, the focus of this protocol, are adjusted through a separate set of actions to report net savings. Net savings are only those savings that can be attributed to the program. The concept of net savings recognizes that some participants would have acted on their own to adopt energy efficiency strategies, might have installed additional equipment as a result of increased awareness of the value of energy efficiency through their participation, or improved their energy efficiency operations due to market changes induced by a program’s operations. For more on net savings, see UMP *Chapter 21: Estimating Net Savings – Common Practices*.

Steps taken by the evaluator under this protocol include:

1. Reviewing a statistically significant random sample of completed projects, including conducting on-site M&V activities
2. Calculating a gross realization rate (the ratio of evaluator-to-implementer anticipated gross savings)
3. Using the realization rate to adjust the implementer-estimated gross savings.

5.1 Evaluator Data Requirements

This protocol recommends the impact evaluator collect the same data as the implementer. As described in Section 6, the evaluator must have access to the implementation lighting inventory forms and participant application material for each project in the sample. For some program types, specifically midstream and upstream, the evaluator will collect more data than the implementer. This is the case when the evaluator conducts onsite verification of baseline conditions for a midstream program.

5.2 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. That record contains the fields specified 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 Data Required by Evaluator

Field	Note
Location	From implementer
Usage group	From implementer
Location heating	From implementer, verified by evaluator
Location heating type	From implementer, verified by evaluator
Location heating fuel	From implementer, verified by evaluator
Location cooling	From implementer, verified by evaluator
Location cooling type	From implementer, verified by evaluator
Location cooling fuel	From implementer, verified by evaluator.
Baseline fixture type	From implementer, verified by evaluator
Baseline fixture count	From implementer, verified by evaluator
Baseline fixture watt	From implementer, verified by evaluator
Baseline HOU	From implementer, verified by evaluator
Efficient fixture type	From implementer, verified by evaluator
Efficient fixture count	From implementer, verified by evaluator
Efficient fixture watt	From implementer, verified by evaluator
Efficient lighting HOU	Measured by evaluator
IF_{cool}, or COP_{cool} and HOU_{cool}	Interactive factor for cooling from look-up table, or site-specific COP_{cool} and HOU_{cool} (optional)
IF_{heat}, or COP_{heat} and HOU_{heat}	Interactive factor for heating from look-up table, or site-specific COP_{heat} and HOU_{heat} (optional)
ISR	Measured by evaluator
kWh_{save}	Calculated using savings algorithms
$kW\text{-}Peak_{save}$	Calculated using savings algorithms

6 Measurement and Verification Plan

The M&V plan describes how evaluators determine actual energy savings in a facility where a lighting efficiency project has been installed. Evaluators use M&V to establish energy savings for a random sample of projects. The M&V results are applied to the population of all completed projects to determine program gross savings. The sampling and application processes are described in UMP *Chapter 11: Sample Design Cross-Cutting Protocol*. The sample size should be determined following the recommendations in UMP Chapter 11.

All M&V activities in the protocol are conducted on a representative sample of completed projects, drawn from a closed reporting period (for example, a program year).

6.1 IPMVP Option

The protocol recommends evaluators conduct M&V according to the International Performance Measurement and Verification Protocol (IPMVP) Option A—Retrofit Isolation: Key Parameter Measurement approach.

The key measured parameters are the HOU terms in Equation 1. The fixture quantity parameter is verified through an inspection process. The fixture wattage parameter is verified through a combination of on-site inspections and look-up tables of fixture demand (Watts).

Option A is recommended because the demand (Watts) values are known and published for nearly all fixture types and configurations, and therefore need not be measured, whereas lighting operating hours vary widely from building to building.

6.2 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 fixture wattage and fixture quantity parameters in Equation 1.

The process includes the following steps:

1. Select a representative sample of projects for review (see UMP *Chapter 11: Sample Design Cross-Cutting Protocol* 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. Inspect a representative sample of the energy efficiency lighting fixtures reported by the implementer. The protocol recommends selecting the sample from the implementer's inventory records before going on site (see UMP *Chapter 11: Sample Design Cross-Cutting Protocol* for guidance on sampling.)
4. Confirm or correct the reported energy-efficient fixture type and wattage for each fixture in the sample.
5. Confirm or correct the reported quantity for all energy-efficient fixtures in the sample.
6. Confirm or correct the heating/cooling status and associated equipment for the spaces in the sample.

7. Interview facility representatives to check baseline fixture types and quantities reported for the sample. Confirmation or correction is based on the interviews. When available, interviews are supplemented by physical evidence, such as: fixture types in areas not changed by the project, replacement stock for lamps and ballasts, and/or stockpiles of removed fixtures/lamps stored on-site for recycle or disposal.
8. Update lighting inventory form for the sample, based on findings from the on-site review.

The implementer has the primary responsibility for maintaining accurate project inventories that support evaluation research, including locations of individual fixtures or lamps. An example of an inventory form that meets the requirements of the protocol is provided in the Appendix.

Evaluators may have difficulty locating fixtures or lamps that contribute to a program's reported savings when project records are incomplete, information about fixture or lamp location and type is imprecise, the facility representative guiding the evaluator during a site visit is unfamiliar with the project, or the facility has undergone a change in ownership or retrofit since the project was completed.

When faced with incomplete information, evaluators can use a mix of strategies to conduct verification site visits. If a line in the inventory cannot be located, the verification sample can be expanded to include an entire floor, wing, or other space, and all of the fixtures within the space counted and identified. This approach works when room numbers are not provided in the inventory, for example. Another strategy is to substitute a room or space for one that cannot be located. This can work when there are large numbers of identical spaces such as classrooms, offices, and restrooms. Another is to contact the lighting contractor who installed the efficient lighting products. Contractors have to create their own inventories to manage construction and order material for all lighting projects, and they may be willing to share their lists.

Evaluation field staff will need to exercise judgement when using these strategies as to whether or not to count as verified any fixtures and lamps that cannot be located. The evidence can be inconclusive but still support a reasonable inference.

At the completion of the verification process, the evaluator has confirmed or corrected the fixture wattage and fixture quantity parameters in Equation 1. The process for determining the HOU parameters is described in the following section.

6.3 Measurement Process

The measurement process involves using electronic metering equipment to collect the data for determining the HOU parameters in Equation 1. Most often, the equipment is installed temporarily during the measurement period. Energy management systems that monitor lighting circuits can also be used to measure HOU.

Metering equipment used to measure lighting operating hours either records a change of state (light on, light off) or continuously samples and records current in a lighting circuit or light output of a fixture. All data must be time-stamped for application in the protocol.

6.3.1 Use of Data Loggers

Lighting operating hours are typically determined through the use of temporary equipment such as data loggers.

Change-of-state lighting data loggers are small (matchbox size) integrated devices, which include a photocell, a microprocessor, and memory. The data logger is mounted temporarily inside a fixture (or in proximity to it) and is calibrated to the light output of the fixture. Each time the lamp(s) in the fixture are turned on or off, the event is recorded and time-stamped.

Data loggers that continuously sample and record lighting operating hour information 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 the lights on and off establish the threshold amperage for the on condition. Similarly, a data logger with an external photocell can record light levels in a space. Spot measurements of lumen levels with the fixtures on and off establish the light level threshold for the on condition.

Although measuring amperage with data loggers is common, the continuous monitoring of lumen levels to determine hours of operation is less common.

Data logger failure commonly occurs due to incorrect adjustments, locations, or software launch. Thus, this protocol recommends following manufacturer recommendations carefully and deploying extra loggers as a cushion against failure.

6.3.2 Metering

The measurement process involves metering lighting operating hours for the representative sample of fixtures selected for the verification process. Meters are deployed or trends set up in an existing energy management system during the verification site visit.

This process entails the following activities:

1. Meter operating hours for each circuit in the verification sample.
    A. Develop a metering plan that includes the location of a random selection of required metering points (the metering sample) by usage group. Guidance on sampling is provided in UMP *Chapter 11: Sample Design Cross-Cutting Protocol*. The plan should be developed before going on site. If the inventory is missing good location information, the plan can be adjusted while in the field to make sure the number of metering points by usage group is maintained and that the selection remains random to the extent possible.
    B. If using light loggers, deploy loggers in one or more fixtures controlled by the circuit. Only one logger is required per circuit; additional loggers may be deployed to offset logger failure or loss. A rule of thumb is to install the number of loggers specified in the metering plan for each usage group plus an additional 10%.
    C. If measuring amperage, install CT and data logger in a lighting panel for a sampled circuit. The sampling interval should be 15 minutes or less. Spot-

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

   D. If using an energy management system, program it to sample and record lighting on/off status for each circuit in the sample. The sampling interval should be 15 minutes or less. Check that the energy management system has sufficient capacity to archive recorded data, and that the metering task will not adversely slow system response times.

2. Check data logger operation. 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 to be systemic, redeploy the loggers. If using energy management system trends, spot-check recorded data.

3. Leave the metering equipment in place for the duration of the monitoring period. The protocol recommends a monitoring period that captures the full range of facility operating schedules. The following are some rules of thumb for specifying the length of the monitoring period. More detailed guidance is provided Section 6.3.3.

   A. For facilities with constant schedules (such as office buildings, grocery stores, and retail shops), the protocol requires metering for a minimum of four weeks. The weeks should not be abnormal (e.g. during the end-of-year holidays).

   B. For facilities with variable or irregular schedules, additional metering time is required. The protocol recommends a monitoring period long enough to capture the average operation over the full range of variable schedules.

   C. Facilities with seasonal schedules, such as schools, should be monitored during active periods; additional monitoring can be done during the inactive periods, or if the expected additional savings are small, the hours can be estimated as a percent of active period hours.

4. Analyze metering data. Calculate the percent on-time for the metered lighting equipment for each usage group. Percent on-time is the number of hours the lighting equipment is on divided by the total number of hours in the metering period. Annual lighting hours are the percent on-time times 8,760 hours per year less any closed hours such as for holidays. Separate on-time factors can be developed for day-of-week, month-of-year, and seasonal timeframes if the metered data capture the full range of operations for the more granular reporting period.

   A. For facilities with constant or variable schedules, the HOU parameter is calculated as: 8,760 hours per year, less any hours when the facility is closed for holidays, times the percent-on time.

   B. For facilities with seasonal schedules, the HOU parameter is: the hours/year in the active or operational period, times the percent-on time.

   C. The data used in the analysis should represent a typical schedule cycle. For example, 28 full days for an office space occupied Monday through Friday and unoccupied on weekends. The hours/year in the active period may vary by usage group; in schools, for example, office spaces may be active 8,760 hours/year, while classrooms are only active 6,570 hours/year.

5. Evaluation timing usually requires the measurement of operating hours after the efficiency project has been completed. This process assumes that the operating hours are unchanged from the baseline period. Thus, HOU baseline and HOU energy-efficient in Equation 1 have the same value. (Note that will not be the case if the project includes lighting control measures.)
6. UMP *Chapter 3: Commercial and Industrial Lighting Controls Evaluation Protocol* addresses lighting control measures, but Equation 1 can accommodate changes in lighting operating hours, as would occur in combined lighting equipment and lighting controls projects, provided measured hours of use data are available for the baseline period. For example, these data may be available for a facility with an energy management system with archived trends or if a lighting contractor conducted a metering study before entering into a performance contract.

6.3.3 Duration of Metering Period

While a metering period of one year would provide the most accurate picture of a facility's lighting HOU, economic and customer considerations impose practical limits on the actual duration. Regulators, program administrators, and customers have limits to their tolerance for lengthy evaluation periods that delay studies and their results, and that require on-going facility coordination. Evaluators are thus faced with the questions, "What is the optimal length of a metering study to obtain acceptable estimates of annual lighting hours of use?" and "How accurate is this optimal estimate?" A recent study conducted for a Massachusetts large commercial/industrial program provides some answers (KEMA 2013).

This protocol recommends a one-month minimum metering period based, in part, on the results of this long-term Massachusetts study.

The study included 12 months of continuous monitoring of lighting systems at 34 large commercial and industrial sites. Evaluators estimated gross annual savings from each month of data collected, as well as for each two- and three-month block of data collected. The three-month results were later compared to the full 12-month study results to determine how well these shorter metering periods results following completion of the full year of monitoring. The key findings were that a three-month period of monitoring did a reasonable job of estimating full year savings as compared to the 12 months of monitoring. **Error! Reference source not found.** below presents the HOU and summer coincidence factors by building type from both monitoring periods. A value greater than 100% means that the full year was higher than the three-month estimate, or that the three-month data underestimated these parameters. Due to the seasonal usage, school/university-type buildings were more difficult to annualize and estimate summer coincidence factors from three months of data.

For most sites, the three-month period included winter/spring months. Fewer daylight hours in the winter as compared to summer in the northern hemisphere explain why the three-month results overestimated HOU and CF for this building type as compared to the full 12-month study.

Table 3. Comparison of 12-Month and 3-Month HOU and Summer CF by Building Type

Building Type	Count of Building Type	3-Month Data - Annualized HOU	Actual 12-Month Data HOU	12-Month/ 3-Month HOU	3-Month Data - Estimated Summer CF	Actual 12-Month Data Summer CF	12-Month/ 3-Month CF
Manufacturing (n=6)	6	5,898	5,730	97%	88%	88%	100%
Office (n=5)	5	4,079	3,759	92%	89%	81%	91%
Retail (n=5)	5	5,727	5,473	96%	91%	91%	100%
School/University (n=4)	4	3,114	2,839	91%	54%	39%	72%
Exercise Center (n=2)	2	6,541	6,604	101%	89%	91%	102%
Library (n=2)	2	2,129	1,990	93%	58%	58%	101%
Other (n=10)	10	6,054	5,965	99%	81%	79%	98%
All Lighting Systems (n=34)	34	5,140	4,963	97%	81%	77%	96%

The study also looked at the differences in annual energy savings when using blocks of one-, two-, and three-month metering periods compared to the 12-month study results, as summarized in Table 4. The percentages represent how close the annual energy savings would have been compared to the full 12-month results had data from each specified that period been used to estimate annual energy savings. Each of the monitoring periods were able to produce annual energy savings estimates to within 10% of the full 12-month result, which is the basis for the protocol's recommendation for a one-month metering minimum. As more data were included, the annual savings estimates improved. By including three months of data, evaluators could estimate annual energy savings to within 5% of the full 12-month result regardless of the specific three-month period.

Table 4. Comparison of 1-, 2-, and 3-Month Metering to Actual 12-Month Energy Savings

Monitored One Month	Percent of Actual Annual Energy Savings	Monitored Two Month Period	Percent of Actual Annual Energy Savings	Monitored Three Month Period	Percent of Actual Annual Energy Savings
January	99%	Jan-Feb	95%	Jan-Mar	97%
February	90%	Feb-Mar	95%	Feb-Apr	96%
March	101%	Mar-Apr	98%	Mar-May	101%
April	96%	Apr-May	102%	Apr-Jun	102%
May	108%	May-Jun	106%	May-Jul	104%
June	103%	Jun-Jul	103%	Jun-Aug	103%
July	102%	Jul-Aug	103%	Jul-Sept	102%
August	104%	Aug-Sept	103%	Aug-Oct	103%
September	101%	Sept-Oct	103%	Sept-Nov	100%
October	105%	Oct-Nov	99%	Nov-Jan	97%
November	94%	Nov-Dec	96%	Oct-Dec	99%
December	98%	Dec-Jan	98%	Dec-Feb	96%

If either winter or summer peak demand savings are of concern, the protocol recommends including at least one winter or one summer month in the monitoring period. If both winter and summer peak demand savings are equally important, the protocol recommends monitoring during both seasons. Note that monitoring for both seasons extends the study timeline to at least nine months and increases the overall cost.

6.4 Report M&V and Program Gross Savings

Information collected during the M&V processes is used to calculate M&V project savings, as follows:

1. Using the results from the last step in verification process, update the inventory HOU parameters and calculate M&V savings for the sample of projects.
2. Calculate the program gross realization rate, the verified project savings divided by the reported project savings for the sampled projects.

Equation 10. Program Gross Realization Rate

$$Gross\ Realization\ Rate_{kWh,kW} = \frac{\sum kWh, kW_{M\&V}}{\sum kWh, kW_{Reported}}$$

3. Calculate the evaluated program savings, the product of the program realization rate and the program reported savings.

Equation 11. Evaluated Program Savings

$$Evaluated\ Savings_{kWh,kW} = Gross\ Realization\ Rate_{kWh,kW} \cdot kWh, kW_{Reported}$$

The uncertainty and, therefore, the reliability of the program realization rate depend on the sample size and variance in the findings (described in *Chapter 11: Sample Design Cross-Cutting Protocol*). These are usually a function of the confidence and precision targets stipulated by regulators or administrators, and evaluation budgets. The sample sizes for homogeneous lighting efficiency programs can range from as few as 12 for an 80/20 confidence/precision target to as many as 68 (or more) for a 90/10 target, assuming an average coefficient of variation of 0.5. Higher coefficient of variations will result in larger samples.

The confidence level and its associated precision of the evaluated savings in

Equation 11 should be included when reporting results; for example, 732 MWh/year ±7% (relative), or 732 MWh/year ±51.2 MWh/year (absolute) at 90% confidence. UMP *Chapter 11: Sample Design Cross-Cutting Protocol* describes the calculation of precision for reported savings. A worked example showing the precision calculations for reported savings from a lighting project is also available as part of the IPMVP.[4]

Precision can only be calculated for the metering period. Care should be taken to ensure that the metering period is representative of the entire year as described in Section 6.3.3.

6.5 Data Requirements and Sources

This section contains information on the fixture wattage, annual HOU, interactive cooling, and interactive heating factor parameters found in the algorithm equations. Data requirements are described in Section 4 *Role of the Lighting Program Implementer* and Section 5 *Role of the Evaluator*, with additional detail in Section 6 *Measurement and Verification Plan*.

6.5.1 Fixture Wattage

The protocol recommends use of fixture wattage tables, developed and maintained by existing energy efficiency programs and associated regulatory agencies. The tables list all common fixture types. Most tables are updated as new fixtures and lighting technologies become available.

The wattage values are measured according to ANSI standards[5] by research facilities working on behalf of manufacturers and academic laboratories (CEC 1993).

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 a lighting inventory form, which, if programmed, can search by a look-up function to show the associated demand. The evaluator

4 IPMVP, Uncertainty Assessment. Anticipated to be available to the public winter of 2018. http://evo-world.org/en/

5 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 wattage will vary, depending on the installation (suspended, recessed) and housing type. Differences are small—less than 5%.

then verifies or corrects the fixture type for the evaluation sample, updating the lighting wattage values if needed.

Fixture wattage tables do not include records for many LED fixtures and lamps in part because the tables lag behind this developing technology, but also because LEDs do not lend themselves to the same clear-cut classifications used for older technologies such as fluorescent or metal halide. LED fixture codes are needed to classify them by application and cost so they support market trending and cost-effectiveness analysis.

A solution is to allow users to create LED fixture codes that capture type and wattage using a set nomenclature. Following is an example of one scheme:

LEDnXXXXww

Where:

n = number of lamps

XXXX = fixture category from Table 5

ww = fixture wattage from manufacturer cut sheets

Table 5. LED Fixture/Lamp Categories

48" Linear Fluorescent Tube Replacement	LT
24" Linear Fluorescent Tube Replacement	LT
High-Bay Luminaires	HBR
Outdoor Pole/Arm-Mounted Luminaires	OP/A
Outdoor Wall-Mounted Luminaires	OW
Refrigerated Display Case Luminaires	RDL
Street Lamp Luminaires	ST
Custom	C

Thus the fixture code LED1OP/A50 for a 10-lamp, 50-watt outdoor pole/arm-mounted luminaire.

The protocol recommends adopting a fixture wattage table, used by an established and recognized lighting efficiency program. As of August 2017, the following sources provide examples (many others are available in most U.S. regions):

- Massachusetts Program Administrators. (October 2011). *Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures* (October 2015). http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-Plan-1.pdf.
- TecMarket Works. (October 2010). *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs—Residential, Multi-Family and Commercial/Industrial Measures*. (Version 5) (July 2017). Prepared for the New York

Public Service Commission. http://www3.dps.ny.gov/W/PSCWeb.nsf/96f0fec0b45a3c6485257688006a701a/72c23decff52920a85257f1100671bdd/$FILE/TRM%20Version%205%20-%20January%202018.pdf.

- Database for Energy Efficiency Resources (DEER). Available from the California Public Utilities Commission at: 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.

Wattage tables are used by both the implementer and the evaluator. 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.

6.5.2 Hours of Use

The protocol requires the evaluator to measure operating hours for a sample of buildings and fixtures, as described in Section 6.3 *Measurement Process*.

This section describes data sources and methods used by the program implementer for estimating HOU values for individual projects. Accurate estimates of the HOU parameter are needed for the implementer to reliably estimate and report project and program savings. Accurate reporting by the implementer also results in more accurate evaluated savings for a given sample size.

The protocol requires program participants to provide estimates of HOU values by usage group in their lighting inventory forms. The estimate should not be based on the building schedule alone, although this may inform the estimate. Instead, the protocol recommends participants develop the HOU values using one of the following sources, with guidance from the program implementer:

- ***Lighting schedules in buildings with energy management systems or time clocks*** controlling lighting equipment. The project participant should interview the building manager to verify that the schedules are not overridden. Control schedules (or trend data) are reliable estimates of true lighting operating hours, but they are normally available only for larger, newer facilities.
- ***Interviews with building managers.*** Building managers are usually familiar with lighting schedules, and can describe when lights are turned on and off for typical weekdays and weekends. They may not know about abnormalities such as newly vacant spaces, how cleaning crews operate lights, or whether lights are actually turned off after hours. The protocol recommends interviewing two or more people familiar with a facility's operation to verify scheduling assumptions.
- ***Tables of HOU values by building type*** provided by the program implementer. HOU values have been developed from impact evaluation and M&V studies for many commercial and nonresidential buildings. Like wattage tables, HOU tables are maintained by energy efficiency programs and associated regulatory agencies; sources can be found using the same references provided for wattage tables. 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 table of HOU values.

Actual operating schedules vary widely for any given building type, and tabulated average values contain larger variations than values for fixture wattages. Also, tabulated HOU values are given for entire buildings, not by usage groups within buildings. The protocol requires HOU estimates be entered into the inventory by usage group, which will vary from the building average. For these reasons, the protocol recommends use of building-specific lighting operating hours when these are available, supplemented if necessary by tables of HOU values.

6.5.3 Interactive Cooling and Heating

Energy-efficient lighting equipment contributes less waste heat to building conditioned spaces, compared to baseline equipment. This results in a reduced cooling and increased heating loads.

This protocol provides two options for calculating interactive cooling and heating effects: an engineering approach and a stipulated factor approach. A third approach, simulation modeling, is also an option; however, it tends to be labor-intensive and is usually reserved for large-scale studies used to quantify stipulated factors. It is unusual to model interactive savings on a project-by-project basis, and it is not required by the protocol.

The engineering approach requires site-specific estimates of the COP for the cooling and heating equipment, and the lighting HOU coincident with the cooling or heating equipment operation. These values can be developed from information gathered during site visits conducted as part of the verification process.

6.5.3.1 Interactive Cooling and Heating – Stipulated Approach

The stipulated factor approach uses interactive factors—terms IF_{cool} and IF_{heat} in Section 3.1 *Algorithms*—to account for the additional changes in cooling or heating energy use. Values are dependent on the type of facility, regional climatic conditions, and cooling and heating equipment. Guidance is provided below for several common situations.

Interactive cooling effects are generally small for spaces conditioned for human comfort (2% to 6% for cooling in offices in New York City, for example) (TecMarket Works 2010). They are also highly dependent on HVAC system types and efficiencies. For example, in a large office building in New York City, the IF_{cool} varies with the equipment: (1) with gas heat and no economizer, the IF_{cool} is 3.3%, (2) with an economizer, the IF_{cool} is 1.9%, and (3) with economizer and a variable air volume system, the IF_{cool} is 6.5%. In regions with hot climates where cooling loads are higher than in New York City, IF_{cool} values will be larger than these examples. In cooler climates, the values will be lower.

Interactive heating effects are also small for conditioned spaces and will vary with HVAC system types and efficiencies. For example, in a large office building in New York City, the IF_{heat} ranges from -2.2% to -1.3% (TecMarket Works 2010). The negative value indicates that decrease in waste thermal energy from the efficient lighting equipment must be replaced by the heating system.

Electric efficiency programs often ignore interactive heating effects when territory's heating systems are primarily nonelectric; e.g., natural gas or oil. For comprehensive programs with an all-fuels reporting responsibility, or where electric heating is significant, the increased heating energy can be included.

Interactive factors are usually too small to be measured accurately; instead, they are developed using computer simulations and the interactive impacts are stipulated. Interactive effects are available from the same sources as fixture wattages and HOU.

Interactive effects can be significant in cold-temperature conditioned spaces, such as freezers or refrigerated warehouses. For example, in Pennsylvania, the default interactive cooling factors are defined by space temperature ranges as follows (Pennsylvania Public Utility Commission 2016):

- Freezer spaces (-20 °F–27 °F) = 50%
- Medium-temperature refrigerated spaces (28 °F–40 °F) = 29%
- High-temperature refrigerated spaces (47 °F–60 °F) = 18%
- Uncooled space (e.g. warehouse with no mechanical cooling) = 0%.

Not all programs estimate, report, and evaluate interactive effects, and the decision is often a policy choice. Further, because programs are often energy specific (electricity or gas), the effect on other fuels is sometimes ignored. For example, electric energy efficiency programs might report interactive electric cooling savings, but omit interactive increases in gas heating energy.

A sample of IFs can be found in the documents listed in *Resources*.

6.5.3.2 Interactive Cooling and Heating – Engineering Approach

A complete description of the engineering approach to estimating interactive cooling and heating effects is provided in Section 3.1.1 *Energy Savings.*

6.5.4 Coincidence Factors (CF)

CFs adjust the change in connected electric load from lighting efficiency projects for electric peak demand savings. Electric demand savings that occur during utility system peak periods help lower utility capacity requirements, reduce the load on peak generation equipment that is usually the costliest to operate, and improve system reliability. The value of peak demand generation is reflected in rate structures that charge customers for their demand during peak time-of-use periods.

CFs can range from a high of 1.0 down to 0.0, where 1.0 indicates that 100% of a lighting project's change in connected load occurs during the utility peak period. An example is the CF of 1.0 for commercial lighting efficiency projects in New York State (TecMarket Works 2010). Dawn-to-dusk exterior lighting has a CF of 0.0 when system peaks occur during daylight hours, which is normal for most utilities. Some programs or utilities may have very specific targets for the timing of demand reductions. For example, the Con Edison Brooklyn Queens Demand Management Program targets savings from 9 p.m. to 10 p.m. on weekdays. Use of typical commercial CF for such a program is not advised.

CFs can be developed from lighting HOU meter data. The CF is the peak period energized lighting kW as measured by the meter data, divided by the total connected kW for the energy efficiency lighting project.

This protocol recommends using tables of CFs (including any interactive effects from reduced cooling loads) to report system peak coincident electric demand savings. If regulators or program administrators require greater reliability for evaluated demand reductions (as would occur for a program designed to increase capacity reserves), CFs should be developed from metered data. Like IFs, unique CFs can also be adapted from programs with similar customer and utility profiles.

A sample of CFs can be found in the documents listed in *Resources*. CFs are also discussed in UMP *Chapter 10: Peak Demand and Time-Differentiated Energy Savings Cross-Cutting Protocol*.

7 Gross Impact Evaluation

Gross impact evaluations entail a detailed review of a random sample of completed projects, concluding with an independent assessment of their gross savings. The ratio of program-claimed savings and gross evaluated savings for the projects (the gross realization rate) is used to adjust claimed savings for all completed projects (the program).

Gross impact evaluations are coordinated in conjunction with program milestones, usually at the end of a program year or cycle. The evaluation's subject is the population of all projects completed up to the milestone.

It is preferable to begin evaluation activity before the program cycle ends, because difficulties and inaccuracies often occur when collecting data retroactively, particularly in attempts to backfill missing data, determine baseline data, or deal with poor customer recall of project details. This may require drawing a preliminary sample before the milestone date and then adjusting (adding to) the sample after the milestone date.

The evaluator uses the same algorithms and data as the program implementer (subject to review and site inspections), except that HOU values are based on measurements of actual lighting operating hours for all projects in the evaluation sample, and lighting inventories (including baseline and energy efficiency fixture types and counts) are corrected as needed based on on-site reviews of the sample projects.

The ratio of evaluator savings to program reported savings for the projects in the M&V sample is the program realization rate. Total reported program savings for the reporting period are then multiplied by the program realization rate to determine program evaluated savings for the period.

Realization rates can also be developed for facility and customer types if the implementer is interested in the savings performance of these sub-populations.

7.1 Sample Design

The protocol requires sampling to select:

- Projects from a program database for an impact study
- Inventory lines for deploying light loggers.

Regulators normally prescribe the confidence and precision levels for the sample, or the implementer may impose them. UMP *Chapter 11: Sample Design Cross-Cutting Protocol* describes general sampling procedures and should be consulted when developing evaluation plans for lighting efficiency programs. The following details pertain specifically to lighting.

The protocol recommends stratified sampling when selecting projects for an impact study because it usually results in smaller sample sizes as compared to simple random sampling. The idea behind stratified sampling is to select subpopulations of relatively homogeneous projects such that the variance within each stratum is smaller than for the population as a whole, as explained in UMP *Chapter 11: Sample Design Cross-Cutting Protocol*.

A simplified stratified strategy is to rank all projects in the population to be studied by their reported savings (ranked from largest to smallest) and to define three strata. The top stratum contains large projects that cumulatively account for 50% of reported savings, and the remaining projects are grouped into medium strata contributing 30% and small strata contributing 20%.

A more rigorous method is to use a stratified strategy with a customized stratum threshold where techniques are employed to define strata that minimize the expected variance in their realization rates, and thereby minimize the sample size. The stratification thresholds are designed to minimize the variance of a stratified ratio estimator. Stratified ratio estimation is fully explained in UMP *Chapter 11: Sample Design Cross-Cutting Protocol*, which should be referenced when developing sampling plans. Projects may also be stratified by technology types, or by other characteristics, if known, such as business type or primary space type of the installations.

Light-logger studies also use stratified sampling within projects selected for M&V by selecting samples of fixtures for metering, with strata defined by usage groups. The desired confidence and precision interval (typically prescribed with an assumed coefficient of variation of 0.5) determines the sample size. The Federal Energy Management Program M&V Guidelines (Federal Energy Management Program 2008) describe a detailed routine for selecting logging lines.

Oversampling of projects by 30% and of loggers within projects by 10% is recommended to replace participants that cannot be scheduled for a site visit, and to provide a cushion against lost or failed loggers in HOU studies.

8 Other Evaluation Issues

8.1 Upstream/Midstream Delivery

As upstream programs do not interact with individual customers, they lack the lighting inventory forms (with associated data) used to estimate savings. Implementers and evaluators can use sales data, surveys, saturation studies, and other indirect methods to estimate baseline fixture wattages and facility HOUs. Implementers and evaluators can also draw on incentive and rebate program data by analyzing baseline fixtures and operating hours associated with fixtures promoted in the upstream buy-down program, thereby developing savings factors for upstream buy-down equipment.

Midstream programs are a subset of the upstream family where incentives for qualified lighting products are paid to distributors selling to contractors and facility managers. Implementers can leverage the distributor-purchaser relationship to collect key information needed for evaluation. This information includes the purchased equipment and the site where it will be installed. Many of the details such as baseline equipment, scheduling, and lighting HOU for the installation site facility must be collected after the sale, by the evaluator, on a random sampling basis. The implementer must make assumptions for these and deem them to report savings. Table 6 lists data required for each project in an evaluation sample, and shows the source of each element.

Table 6. Lighting Data Required by Evaluator for Midstream Programs

Field	Data Source	
	Implementer	Evaluator
Facility	Distributor invoice	From implementer
Facility type	Distributor or utility account	Evaluator data gathering
Usage group	Not reported	Evaluator data gathering
Facility heating (yes/no)	Deemed	Evaluator data gathering
Facility heating type	Deemed	Evaluator data gathering
Facility heating fuel	Deemed	Evaluator data gathering
Facility cooling	Deemed	Evaluator data gathering
Facility cooling type	Deemed	Evaluator data gathering
Facility cooling fuel	Deemed	Evaluator data gathering
Baseline fixture type	Deemed based on efficient fixture type	Evaluator data gathering
Baseline fixture count	Deemed based on efficient fixture count	Evaluator data gathering
Baseline fixture watt	Deemed based on efficient fixture type	Evaluator data gathering
Baseline HOU	Deemed based on facility type	Evaluator data gathering
Usage group	Not reported	Evaluator data gathering
Efficient fixture type	Distributor invoice	From implementer
Efficient fixture count	Distributor invoice	From implementer
Efficient fixture watt	Distributor invoice, qualified products list	From implementer
Efficient lighting HOU	Deemed, look-up table by facility type	Measured by evaluator
IF_{cool}, or COP_{cool} and HOU_{cool}	Deemed, look-up table by facility type	Interactive factor for cooling, from look-up table or evaluator data gathering, optional
$IF_{heat,}$ or COP_{heat} and HOU_{heat}	Deemed, look-up table by facility type	Interactive factor for heating, from look-up table or evaluator data gathering, optional

Field	Data Source	
	Implementer	Evaluator
ISR	Deemed based on previous studies	Evaluator data gathering
kWh_{save}	Calculated using savings algorithms	Calculated using savings algorithms
$kW\text{-}Peak_{save}$	Calculated using savings algorithms	Calculated using savings algorithms

8.1.1 Role of the Implementer in Lighting Midstream Programs

Successful application of this protocol to midstream lighting programs requires collecting standard data in a prescribed format as part of the implementation process. The protocol further requires tracking project and program savings estimated on the basis of those standard data.

Distributors are required to submit sales invoices to the implementer. Invoices capture the efficient lighting product type, specifications, and quantity for each purchase.

Because the implementer does not have contact with end-users who purchase efficient lighting products through midstream programs, savings estimates must make assumptions for five baseline variables used in Section 3.1 equations. Following are standard approaches to determining the baseline assumptions for the five variables used to report program savings. The assumptions and savings are subject to revision by an evaluation review.

1. **Baseline fixture/lamp wattage.** Most programs will use a replace-on-burnout baseline where existing equipment would fail and likely be replaced by a minimally code- or standard-compliant product, or the most commonly installed product if not regulated. Thus, the implementer will match each efficient product with a baseline specification using codes and standards, or market practice. For example, a four-foot LED tube is assumed to replace a T8 lamp. Another example, high bay LED fixtures can be mapped to high-intensity discharge (HID) fixtures using lumen bins; a 15,500 to 20,100 high bay LED replaces a 462-watt (400-watt lamp) metal halide fixture. An example of table-mapping high bay LED fixtures to baseline HID fixtures is provided in the Appendix. In midstream programs, the evaluator can determine, based on site visits, if an early replacement baseline should be used rather than replace-on-burnout.

2. **Baseline fixture/lamp quantity.** Assume a one-for-one replacement. Baseline quantity is equal to the efficient product quantity.

3. **Annual HOU.** Identify the building type where the efficient product is installed and use look-up table to select HOU values by building type. The building type can be identified by using business name, address, and utility account number for each sale, or by requiring distributors to collect it at the point of purchase.

4. **Interactive cooling factor, or cooling equipment COP.** Use look-up table of deemed interactive factor or equipment COP by building type.

5. **Interactive heating factor, or heating equipment COP.** Use look-up table of deemed interactive factor or equipment COP by building type.

The implementer uses the invoice and assumed baseline data to report savings using the equations in Section 3.1.

The implementer is responsible for ensuring all necessary data are collected to track program activity and to calculate savings at the project level. The implementer is responsible for maintaining a program activity record, including anticipated savings by project.

8.1.2 Role of the Evaluator in Lighting Midstream Programs

As described in Section 5, the evaluator's role in midstream programs is to determine energy savings resulting from the operation of lighting efficiency programs. The unique feature for midstream programs is the need to collect more of the baseline and facility data for each project in the evaluation sample as indicated in Table 6. The steps in this procedure include:

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

8.1.2.1 Evaluator Data Requirements

The protocol recommends that the program evaluator develop the same data as the implementer. However, for midstream programs, the sources for most of the data points will be different for each party; the implementer is forced to make assumptions for the baseline and facility while the evaluator contacts each facility in the evaluation sample to verify the actual conditions. The evaluator must have access to the distributor sales data for the sample of incentivized lighting products, including information about the facility where they are installed.

8.1.2.2 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. That record contains the fields specified in Table 6. The implementer also provides all records for projects in the evaluation review sample, including application materials and site contact information.

This protocol recommends the evaluator collect M&V data during site visits conducted for the sample of evaluation review projects. The data include information about the baseline equipment using the same techniques as for rebate and incentive programs. The data are used to update assumptions and values made by the implementer. Table 6 lists data required for each project in the evaluation sample.

8.2 New Construction

Installed power (kW) savings for new construction projects are calculated by subtracting as-built building lighting power from the lighting power of a code-compliant alternative, or common practice. The code-compliant alternative or common practice is the baseline. For jurisdictions where common practice is more efficient than code, a common practice baseline should be used. This is occurring in regions where LED lighting is specified in new construction (as opposed to T8/CFL/Metal Halide technologies). Code defines compliance in terms of lighting power density (LPD, lighting watts/ft^2). Lighting power equals LPD times building area.

New construction codes require controls with automatic lighting shutoff, with some exceptions for safety. The controls reduce the lighting HOU compared to existing facilities. Implementers can use look-up tables of new construction lighting hours of use that account for controls. These tables are available from some of the references in Section 11. Evaluators measure HOU using meters or bulk meter services.

8.3 First Year Versus Lifetime Savings

This protocol provides planners and implementers with a framework for reliable accounting of energy and demand savings resulting from lighting efficiency programs during the first year of measure installation.

Savings over the life of a measure may be less than the product of first-year savings and measure life. The discount results from replacement, degradation, or failure of the efficient equipment. Lifetime savings are covered further in UMP *Chapter 13: Assessing Persistence and Other Evaluation Issues Cross-Cutting Protocol*. However, because lifetime savings for lighting projects are strongly driven by federal standards and changes in the market, they are discussed here.

Most T12 lamps do not meet federal efficacy (lumens/watt) standards that went into effect in July 2012, accelerating a long-term trend toward T8 and T5 lamps and electronic ballasts, or LED tubes or panels. The effect is that first-year savings for T12 to T8, T5, and LED replacements can be assumed only for the remaining useful life of T12 equipment, at which point customers have no choice but to install equipment meeting the new standard.

For retrofit lighting programs, at the time when old equipment would be replaced, there is effectively a step up in the baseline and a step down in the annual savings for the replacement equipment. This leads to a dual baseline:

- An initial baseline with full first-year savings for the remaining useful life of the replaced equipment
- An efficient baseline with reduced savings for the remaining effective useful life of the efficient equipment.

The protocol methodologies, which specify tracking data for each installation, support the calculation of lifetime savings (including the use of a dual baseline).

The remaining useful life can be estimated from research studies. It can also be assumed to be a third of the effective useful life of the baseline equipment.

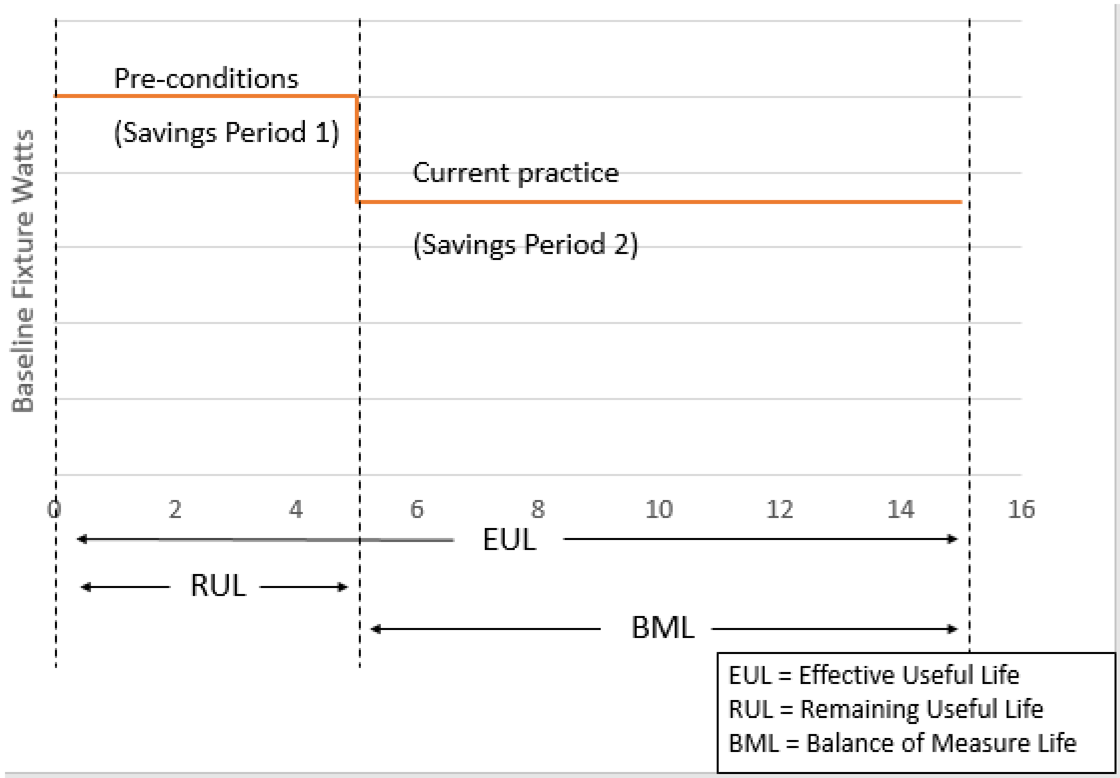

Figure 1. Dual baseline[6]

Figure courtesy of Regional Technical Forum

8.4 Program Evaluation Elements

Setting the foundation for a successful evaluation of a commercial, industrial, non-residential lighting program begins early in the program design phase. Implementers support future evaluations by ensuring data required to conduct an impact study are collected, stored, and checked for quality. These data include measured and estimated values available from past studies or equipment tests. Implementers must set data requirements before a program's launch to ensure the information required to conduct the research will be available.

[6] "Current practice" in the "Savings Period 2" time frame could be codes and standards, or current market practice for products not covered by codes or standards.

9 Looking Forward

Market baseline studies can support gross impact evaluation research of upstream programs by identifying associations between incentivized products and categories of baseline equipment, including their demand and energy patterns. Longitudinal market effects studies can supplement traditional site visit data gathering by characterizing changes over time in lighting equipment installations.

There is a need to develop hybrid approaches for lighting programs that include both market baseline and market effects studies in addition to the sampling and site visit model described in this protocol. As the delivery of lighting energy efficiency changes to include upstream and midstream models along with traditional downstream (rebate) models, as appears to be occurring now, there will be greater need for these market data to 1) establish baselines and 2) quantify gross (and net) savings impacts.

10 References

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Federal Energy Management Program (FEMP). (2008). *M&V Guidelines: Measurement and Verification for Federal Energy Projects Version 4.0*. https://energy.gov/sites/prod/files/2016/01/f28/mv_guide_4_0.pdf.

KEMA, Inc. (June 21, 2013). *Impact Evaluation of 2010 Prescriptive Lighting Installations*. Prepared for the Massachusetts Program Administrators and Massachusetts Energy Efficiency Advisory Council. http://ma-eeac.org/wordpress/wp-content/uploads/Impact-Evaluation-of-2010-Prescriptive-Lighting-Installations-Final-Report-6-21-13.pdf

Pennsylvania Public Utility Commission. (2016). *Technical Reference Manual*, Appendix C. http://www.puc.state.pa.us/filing_resources/issues_laws_regulations/act_129_information/technical_reference_manual.aspx.

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11 Resources

This protocol depends heavily on reliable estimates of fixture wattages and HOU, CF, and IF values. A rich body of publicly available research provides these data, which can be found in the resources listed below. Although this is not an exhaustive list, it is representative. Users should select the references that best match their markets and program needs.

The documents cited below have been produced through regulatory and administrative processes, and, as they were developed with considerable oversight and review, they are considered reliable by each sponsoring jurisdiction for their intended applications. HOU, CF, and IF values have been developed from primary data collected during project M&V reviews or evaluation studies, or they are based on engineering analysis. Some of these references provide source documentation.

Fixture wattages are generally based on manufacturers' ratings, obtained during tests conducted according to ANSI standards, although this is not well documented in these sources. Fixture wattages are independent of geographic location. Also, HOU values also tend to be consistent for non-residential building types regardless of location. The sources cited here can be used for these parameters in any service territory.

IF and CF parameters, on the other hand, are dependent on local conditions (weather and system load shape) and users should select carefully so that the referenced values reflect local conditions. Alternatively, local IF and CF parameters can be developed using computer simulations and system load shapes for the service territory where they will be used.

The following documents have informed the development of this protocol. Users will find them a useful starting point in locating the data required to implement the protocol's savings algorithms and procedures.

California Energy Commission (CEC).

DOE *Advanced Lighting Guidelines*.1993

"Database for Energy Efficient Resources (DEER)." California Public Utilities Commission (CPUC).www.deeresources.com.

Efficiency Valuation Organization (EVO). IPMVP, Uncertainty Assessment. Anticipated to be available to the public winter of 2018. Free registration required to download: http://evo-world.org/en/

Massachusetts Program Administrators. (October 2011). *Massachusetts Technical Reference Manual for Estimating Savings from Energy Efficiency Measures* (October 2015). http://ma-eeac.org/wordpress/wp-content/uploads/2016-2018-Plan-1.pdf.

New York Department of Public Service. (2010). *New York Standard Approach for Estimating Energy Savings from Energy Efficiency Programs.* Prepared for the New York Department of Public Service. Albany, New York: New York Department of Public Service, pp. 109-270.

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

12 Appendix

Table 7. Example Lighting Inventory Form

Project Name:	Example Building Lighting Project #3	**Facility Type:**	Office
Site Name:	Example Building	**Facility Location:**	NYC
Utility Acct Number(s):	XXX-XXXXXXXXXX	**Facility Square Feet**	40,000
Type of Heating Equipment:	Gas fired boiler		
Type of Cooling Equipment:	Rooftop DX	Date(s) Survey completed:	
		Survey completed by (name):	

INSTRUCTIONS

				PRE-INSTALLATION					POST-INSTALLATION										
Area Description	**Usage Group ID**	**Heat?**	**Cool?**	**Pre Fixt. No.**	**Pre Fixt. Code**	**Pre Watts/Fixt**	**Pre kW/Space**	**Existing Control**	**Post Fixt No.**	**Post Fixt Code**	**Post Watts/ Fixt**	**Post kW/Space**	**Proposed Control**	**kW Saved**	**Heating InterActive Factor**	**Cooling InterActive Factor**	**Baseline Annual Hours**	**Proposed Annual Hours**	**Annual kWh Saved**
Unique description of the location that matches the site map	Descriptive name for the usage group	Yes or No	Yes or No	Number of fixtures before the retrofit	Code from Table of Standard Fixture Wattages	Value from Table of Standard Fixture Wattages	(Pre Watts/Fixt) * (Pre Fixt No.)	Pre-installation control device	Number of fixtures after the retrofit	Code from Table of Standard Fixture Wattages	Value from Table of Standard Fixture Wattages	(Post Watts/Fixt) * (Post Fixt No.)	Post-installation control device	(Pre kW/Space) - (Post kW/Space)	Change in heating energy due to lighting project	Change in cooling energy due to lighting project	Existing annual hours for the usage group	Propsed annual hours for the usage group	[(Pre kW/Space * Baseline Annual Hours) - (Post kW/Space * Proposed Annual Hours)] * (1+Heat-IF)
Room 343	Office	Yes	Yes	8	2F40SEM	70	0.56	Switch	8	2F25EEE	43	0.34	Switch	0.22	-	0.03	2,500	2,500	558
Room 344	Office	Yes	Yes	3	2F40SEM	70	0.21	Switch	3	2F25EEE	43	0.13		0.08	-	0.03	2,500	2,500	209
Corridor Floor 3	Hallway	Yes	Yes	17	1F40SEE	38	0.65	Switch	17	1F25EEE	30	0.51		0.14	-	0.03	3,700	3,700	520
Women RR Flr 3	Restroom	Yes	Yes	4	110060	60	0.24	Switch	4	1C00185	20	0.08		0.16	-	0.03	3,700	3,700	612
Men RR Flr 3	Restroom	Yes	Yes	4	110060	60	0.24	Switch	4	1C00185	20	0.08		0.16	-	0.03	3,700	3,700	612
	TOTAL			**36.00**		**298.00**	**1.90**		**36.00**	**1.14**	**156.00**	**1.14**		**0.75**					**2,510**

Table 8. New York Standard Approach for Estimating Energy Savings

FIXTURE CODE	LAMP CODE	DESCRIPTION	BALLAST	Lamp/ fix	WATT/ LAMP	WATT/ FIXT
F42SSILL	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95)	Electronic	2	28	48
F41SSILL/T4	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	28	47
F42SSILL-R	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	28	45
F41SSILL/T4-R	F28T8	Fluorescent, (2) 48", Super T-8 lamp, IS Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	28	44
F42SSILL-H	F28T8	Fluorescent, (2) 48", Super T-8 lamp, Instant Start Ballast, HLO (BF:.96-2.2)	Electronic	2	28	67
F42ILL/T4	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	32	56
F42ILL/T4-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	32	51
F42ILL-H	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, HLO (BF:.96-1.1)	Electronic	2	32	65
F42ILL-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, RLO (BF<0.85)	Electronic	2	32	52
F42ILL-V	F32T8	Fluorescent, (2) 48", T-8 lamp, Instant Start Ballast, VHLO (BF>1.1)	Electronic	2	32	79
F42LE	F32T8	Fluorescent, (2) 48", T-8 lamp	Mag-ES	2	32	71
F42LL	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95)	Electronic	2	32	60
F42LL/T4	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, NLO (BF: .85-.95), Tandem 4 Lamp Ballast	Electronic	2	32	59
F42LL/T4-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85), Tandem 4 Lamp Ballast	Electronic	2	32	53
F42LL-H	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, HLO (BF:.96-1.1)	Electronic	2	32	70
F42LL-R	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, RLO (BF<0.85)	Electronic	2	32	54
F42LL-V	F32T8	Fluorescent, (2) 48", T-8 lamp, Rapid Start Ballast, VHLO (BF>1.1)	Electronic	2	32	85
F42SE	F40T12	Fluorescent, (2) 48", STD lamp	Mag-ES	2	40	86
F42GHL	F48T5/HO	Fluorescent, (2) 48", STD HO T5 lamp	Electronic	2	54	117
F42SHS	F48T12/HO	Fluorescent, (2) 48", STD HO lamp	Mag-STD	2	60	145
F42SIL	F48T12	Fluorescent, (2) 48", STD IS lamp, Electronic ballast	Electronic	2	39	74
F42SIS	F48T12	Fluorescent, (2) 48", STD IS lamp	Mag-STD	2	39	103

(New York Department of Public Service 2010)

Table 9. New York Standard Approach for Estimating Energy Savings

Facility Type	Lighting Hours	Facility Type	Lighting Hours
Auto Related	4,056	Manufacturing Facility	2,857
Bakery	2,854	Medical Offices	3,748
Banks	3,748	Motion Picture Theatre	1,954
Church	1,955	Multi-Family (Common Areas)	7,665
College – Cafeteria (1)	2,713	Museum	3,748
College - Classes/Administrative	2,586	Nursing Homes	5,840
College - Dormitory	3,066	Office (General Office Types) (1)	3,100
Commercial Condos (2)	3,100	Office/Retail	3,748
Convenience Stores	6,376	Parking Garages	4,368
Convention Center	1,954	Parking Lots	4,100
Court House	3,748	Penitentiary	5,477
Dining: Bar Lounge/Leisure	4,182	Performing Arts Theatre	2,586
Dining: Cafeteria / Fast Food	6,456	Police / Fire Stations (24 Hr)	7,665
Dining: Family	4,182	Post Office	3,748
Entertainment	1,952	Pump Stations	1,949
Exercise Center	5,836	Refrigerated Warehouse	2,602
Fast Food Restaurants	6,376	Religious Building	1,955
Fire Station (Unmanned)	1,953	Restaurants	4,182
Food Stores	4,055	Retail	4,057
Gymnasium	2,586	School / University	2,187
Hospitals	7,674	Schools (Jr./Sr. High)	2,187
Hospitals / Health Care	7,666	Schools (Preschool/Elementary)	2,187
Industrial - 1 Shift	2,857	Schools (Technical/Vocational)	2,187
Industrial - 2 Shift	4,730	Small Services	3,750
Industrial - 3 Shift	6,631	Sports Arena	1,954
Laundromats	4,056	Town Hall	3,748
Library	3,748	Transportation	6,456
Light Manufacturers (1)	2,613	Warehouse (Not Refrigerated)	2,602
Lodging (Hotels/Motels)	3,064	Waste Water Treatment Plant	6,631
Mall Concourse	4,833	Workshop	3,750

(New York Department of Public Service 2010)

Table 10. Midstream Baseline Wattage, Linear Lamps, and Fixtures; HID Interior and Exterior Fixtures (Pennsylvania Public Utility Commission 2016)

Efficient Lamp or Fixture	Minimum Lumen	Maximum Lumen	Watts Base	Note
Highbay & Lowbay LED Fixture	3850	6550	189	150-watt HID lamp
	6551	9300	215	175-watt HID lamp
	9301	11150	241	200-watt HID lamp
	11151	12200	295	250-watt HID lamp
	12201	15550	365	320-watt HID lamp
	15551	20100	462	400-watt HID lamp
	20101	34700	843	750-watt HID lamp
	34701	57250	1090	1000-watt HID lamp
Exterior Fixture (Pole, Wall Pack or Parking Garage)	250	4650	133	100-watt HID lamp
	4651	7900	215	175-watt HID lamp
	7901	11050	295	250-watt HID lamp
	11051	24700	462	400-watt HID lamp
	24701	40750	843	750-watt HID lamp
	40751	54650	1090	1,000-watt HID lamp