El Paso Electric

EL PASO ELECTRIC COMPANY'S
COMMERCIAL STANDARD OFFER PROGRAM

MEASUREMENT AND VERIFICATION GUIDELINES FOR RETROFIT AND NEW CONSTRUCTION PROJECTS

This document includes detailed information about the measurement and verification (M&V) requirements of the El Paso Electric Commercial Standard Offer Program, as well as guidance for Project Sponsors on how to prepare and execute an M&V Plan.

Measurement and Verification Guidelines for Retrofit Projects

This section includes detailed information about the measurement and verification (M&V) requirements of the EPE Commercial Standard Offer Program (SOP), as well as guidance for Project Sponsors on how to prepare and execute an M&V plan. These requirements and guidelines are specific to **Retrofit** projects.

NOTICE TO PROJECT SPONSORS

AS OF OCTOBER 2007, A PUCT RULEMAKING IS CURRENTLY UNDERWAY IN ORDER TO IMPLEMENT CHANGES TO ENERGY EFFICIENCY PROGRAMS THAT WERE APPROVED IN THE 2007 LEGISLATIVE SESSION. EPE RESERVES THE RIGHT TO INCORPORATE ANY OR ALL OF THESE CHANGES RESULTING FROM THIS OR OTHER PUCT PROCEEDINGS INTO EPE'S CURRENT-YEAR PROGRAMS AS THEY ARE APPROVED. PROJECT SPONSORS WILL BE PROVIDED WITH ADEQUATE NOTICE OF ANY CHANGES AFFECTING THEIR PROJECTS.

Introduction to Measurement and Verification for Retrofit Projects

Overview

In the El Paso Electric Commercial Standard Offer Program (hereinafter "COMMERCIAL SOP"), the demand and energy savings resulting from a project are determined through measurement and verification (M&V) activities. The M&V methods appropriate for a given measure will depend on the equipment type, operational predictability, and complexity involved in the retrofit. The M&V guidelines provided in the following sections vary in detail and rigor, but fall into three general categories:

- Deemed savings estimates
- Simplified M&V approaches
- Full M&V approaches

The M&V methods presented in this section are guidelines for the Project Sponsor for developing project-specific M&V plans. All M&V plans will necessarily be unique and based on project and site conditions, but may have the common elements discussed here. With the exception of lighting measures and window film measures that qualify for deemed savings, these M&V approaches adhere to the standards of the current *International Performance Measurement and Verification Protocol* (IPMVP). The Project Sponsor is welcome to recommend alternate M&V methods. However, any alternate methods must be approved by EPE and adhere to IPMVP standards.

M&V Approaches

EPE has outlined three distinct M&V approaches, representing increasing levels of detail and rigor - deemed savings, simple M&V, and full M&V. One of these three approaches will be taken for all projects associated with the COMMERCIAL Standard Offer Program. The most appropriate method will depend upon the availability of evaluation data from previous programs for particular measures, the predictability of equipment operation, and the benefits of the method relative to the costs associated with the particular M&V method chosen.

Deemed Savings

Deemed savings refer to a savings estimation approach that does not require short-term testing or long-term metering. Instead, demand and energy savings are stipulated based on evaluation data from past DSM programs or other publicly available industry data. The data are used to make assumptions about typical operating characteristics, manufacturer's nameplate efficiency data, and types of equipment likely to be installed. The deemed savings M&V approach is appropriate for energy efficiency measures for which savings are relatively certain, including lighting efficiency, window films, and some cooling equipment retrofits.

Simple M&V

A simple M&V approach may involve short-term testing or simple long-term metering, but relies primarily on manufacturer's efficiency data and pre-set savings calculation formulas. Simplified methods can reduce the need for some field monitoring or performance testing. For example, chiller energy and demand savings can be determined using the simple approach by comparing rated efficiencies of high-efficiency equipment to standard equipment, and using post-installation kW spot-metering and long-term kWh metering.

Project measures must meet certain criteria in order to determine their savings using a simplified M&V approach. These criteria are described in the M&V guidelines that follow.

Full M&V

Full M&V approaches estimate demand and energy savings using a higher level of rigor than the deemed or simplified M&V approaches through the application of end-use metering, billing regression analysis, or computer simulation. All measures that do not meet the criteria for a more simplified approach must follow full, industry-standard M&V procedures. All Full M&V methods should be developed in accordance with the current International Performance Measurement and Verification Protocol (IPMVP).

Organization of the Guidelines

The COMMERCIAL Standard Offer Program M&V guidelines define appropriate M&V procedures covering the majority of anticipated energy-efficiency measures (EEMs) that will be installed as part of the COMMERCIAL Standard Offer Program. The simplified and full M&V approaches are an application of the IPMVP adapted for use with this program. Table 1 lists the M&V methods provided in the guideline chapters.

Table 1: M&V approaches and guidelines

M&V Guideline	Energy Efficiency Measure	M&V Approach
1	Lighting Efficiency	Deemed or Simple (depending on building type)
2	Lighting Efficiency and Controls	Deemed or Simple (depending on building type)
3	Cooling equipment retrofits	Deemed, Simple or Full (depending on application)
4	Motor retrofits	Simple or Full (depending on application)
5	Window films	Deemed
6	Various – stipulated savings factors	Simple
7	Generic Variable Loads	Full
8	Various – billing analysis using regression models	Full
9	Various – computer modeling and simulation	Full

Measures that cannot utilize the M&V methods presented herein will be evaluated on a case-by-case basis, and M&V procedures will be defined accordingly.

Steps in the M&V Process

Table 2 highlights the basic steps required during the M&V process for most retrofit projects under this program.

Table 2: Steps in the M&V process

Step	M&V Activity	Performed by:
1	Develop a site-specific M&V plan	Project Sponsor and Utility
2	Conduct a pre-installation equipment survey	Project Sponsor
3	Conduct a pre-installation inspection	EPE
4	Install retrofit equipment	Project Sponsor
5	Conduct a post-installation equipment survey	Project Sponsor
6	Conduct a post-installation inspection	EPE
7	Execute the M&V plan (conduct M&V activities if necessary)	Project Sponsor
8	Calculate savings	Project Sponsor

Developing Project-Specific M&V Plans

This section defines the general guidelines for designing a project-specific M&V plan. Issues and requirements specific to each method are further described in the individual guidelines describing specific M&V methods for particular technologies.

The Project Sponsor should work with EPE to identify an M&V methodology and develop an M&V plan that is appropriate for the retrofits being performed as part of each project. The proposed M&V plan must be submitted with the Final Application (FA) for each project, and must be reviewed and approved by EPE.

A project-specific M&V plan shall demonstrate that any proposed metering and analysis will be done in a consistent and logical manner and with a level of accuracy acceptable to all parties. An M&V plan should be prepared for each project to be defined in a contract agreement, as shown on the approved Final Application.

At a minimum, a project-specific M&V plan should address the following (from the IPMVP):

1. Describe the project site and the project; include information on how the project saves energy and what key variables affect the realization of savings.
2. Describe the M&V method to be used.
3. Indicate who will conduct the M&V activities and prepare the M&V analyses and documentation.
4. Define the details of how calculations will be made. For instance: "List analysis tools, such as DOE-2 computer simulations, and/or show the equations to be used." A complete "path" should be defined indicating how collected survey and metering/monitoring data will be used to calculate savings. All equations should be shown.
5. Specify what metering equipment will be used, who will provide the equipment, its accuracy and calibration procedures. Include a metering schedule describing metering duration and when it will occur, and how data from the metering will be validated and reported. Include data formats. Electronic, formatted data read directly from a meter or data logger are recommended for any short- or long-term metering.
6. Define what key assumptions will be made about significant variables or unknowns. For instance: "actual weather data will be used, rather than typical-year data," or "fan power will be metered for one full year for two of the six supply air systems." Describe any stipulations that will be made and the source of data for the stipulations.
7. Define how any baseline adjustments will be made.
8. Describe any sampling that will be used, why it is included, sample sizes, documentation on how sample sizes were selected, and information on how random sample points will be selected.

9. Indicate how quality assurance will be maintained and replication confirmed. For instance: "The data being collected will be checked every month," or "to ensure sufficient accuracy, results will be subjected to third-party review by the ABC company."

1 M&V Guidelines for Retrofit Lighting Efficiency Measures

1.1 Overview

The lighting projects covered by this M&V procedure are lighting efficiency measures that may include the replacement of existing lamps and ballasts with new energy efficient lamps and ballasts.

For these types of projects, demand savings are based on coincident-load factors and changes in lighting load as determined using standard lighting fixture wattage values listed in the EPE Lighting Table of Standard Fixture Wattages (see Appendix C). To determine energy savings, the Project Sponsor should establish operating hours using one of two methods:

Stipulated Hours Method – Energy savings are based on whole building stipulated operating hours established for certain building types (See Table 1.1).

Metered Hours Method – Energy savings are determined by metering post-installation operating hours using defined sampling techniques.

For lighting efficiency measures installed in spaces conditioned with electric refrigerated air systems, demand and energy savings are also given for lighting-HVAC system interaction. These savings are equal to 10% of the lighting demand savings and 5% of lighting energy savings, respectively. Evaporative or alternate fuel system credits for electricity savings must be based on Full M&V results.

In addition to determining operating hours, the Project Sponsor is required to conduct pre- and post-installation equipment surveys. The Project Sponsor should fill out and submit survey results in the standard Lighting Equipment Survey using fixture codes provided in the Table of Standard Fixture Wattages. Refer to Chapter 9 (Final Application) of the Project Sponsor's Manual for an explanation of the Lighting Equipment Survey. EPE or its contractor will conduct pre- and post-installation inspections to verify the reported baseline and retrofit conditions, respectively.

1.2 Stipulated Hours Method

The procedures outlined below should be followed when the project qualifies for using the stipulated hours M&V approach for lighting efficiency projects. Qualifying projects are those accurately characterized by building type and lighting-system operation in Table 1.1. The Stipulated Hours Method may only be used for those building types listed in Table 1.1 without exception. Buildings of types not listed in Table 1.1 are required to use the Metered Hours Method of M&V (see Section 1.3).

1.2.1 Pre-installation M&V Activities

1.2.1.1 Pre-installation equipment survey

Prior to installing the lighting retrofit, the Project Sponsor conducts a pre-installation equipment survey, to be submitted as part of the Final Application. The purpose of the pre-installation equipment survey is to inventory all existing lighting equipment, and to propose the replacement equipment to be installed. This survey should provide the following information about all fixtures: room location, fixture, lamp, and ballast types, lighting controls, area designations, counts of operating and non-operating fixtures, and type of control device. Surveys should include all baseline lighting fixtures and controls, regardless of whether they will be retrofitted. Fixture wattages are based on the fixture codes listed in the Table of Standard Fixture Wattages. This information should be tabulated electronically in the Lighting Equipment Survey.

Non-operating fixtures

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

1.2.1.2 Pre-installation inspection

EPE or its contractor will conduct a pre-installation inspection to verify that the Project Sponsor has properly documented the baseline. The criterion for baseline acceptance is that the error in the installed demand must be within ±5% of the demand reported on the Lighting Equipment Survey. If the error exceeds ±5%, the Project Sponsor is allowed to resubmit corrected lighting tables. If the project fails inspection twice due to incorrect survey forms, the Project Sponsor will bear the cost of subsequent inspections. The cost for each subsequent inspection will be $288. Total costs for all subsequent inspections will be deducted from the incentive amount paid to the Project Sponsor.

The operating hours of the baseline lighting system are assumed to be the same as those of the post-retrofit lighting system and are not measured as part of the pre-installation M&V activities.

1.2.2 Post-installation M&V Activities

1.2.2.1 Post-installation equipment survey

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

1.2.2.2 Post-installation inspection

EPE or its contractor will conduct a post-installation inspection to verify that the retrofit was installed as reported. In most cases, EPE or its contractor will inspect statistically significant samples taken from the entire lighting population. The criterion for acceptance is that the error in the installed demand of the sample must be within ±5% of the demand reported on the post-installation lighting equipment inventory form. If the error exceeds ±5%, EPE will inform the Project Sponsor that the submitted lighting survey must be corrected and resubmitted, citing the major cause of the errors found.

1.2.2.3 Operating hours

The **Stipulated Hours Method** uses stipulated annual operating hours as listed in Table 1.1. If this table does not accurately characterize the building type, then the Project Sponsor should refer to the **Metered Hours Method** section for the appropriate M&V techniques for measuring operating hours for lighting efficiency measures.

Table 1.1: Stipulated Operating Hours, Coincidence Factors, and Interactive Savings

Building Type	Stipulated Annual Operating Hours	Avg. On-Peak Demand Coincidence Factor	Interactive HVAC Demand Savings	Interactive HVAC Energy Savings
24-Hour Supermarket/Retail	6,900	95%	10%	5%
College/University	2,085	67%	10%	5%
Education (K-12; no summer session)	2,150	82%	10%	5%
In-Patient Health Care	3,750	60%	10%	5%
Multi-Family Housing, Common Areas[1]	4,772	87%	10%	5%
Non 24-Hour Supermarket/Retail/Restaurant	4,250	95%	10%	5%
Office	3,760	80%	10%	5%
Parking Structure[1]	7,884	100%	0%	0%

The first column in Table 1.1 presents the stipulated, whole-building, annual operating hours for the building types listed. The retrofit energy savings are determined from the operating hours and the kW reduction determined from the lighting tables. The average on-peak demand coincidence factor (CF) in the second column is the ratio of the average on-peak operating hours of all lighting circuits to the total number of EPE on-peak hours during the monitoring period. The retrofit demand savings are determined from the CF in column two and the kW reduction determined from the Table of Standard Fixture Wattages.

1.2.3 Calculation of Demand and Energy Savings

The peak demand savings and energy savings are calculated according to Equations 1.1 through 1.6. Demand savings are only allowed for lighting fixtures that will be in operation on weekdays between the hours of 1 PM and 7 PM during the months of May through

September. Total demand savings are calculated by multiplying the kW savings by the CF for the appropriate building type, from Table 1.1. The CF is used to adjust total installed lighting demand for the actual percentage of fixtures operating during EPE's peak demand hours. The CF is also applied to the interactive savings since interactive savings are a direct result of lighting operation.

Interactive HVAC demand and energy savings may be calculated using deemed savings multipliers only for lighting retrofits taking place in spaces air-conditioned with electric refrigerated air systems. Lighting retrofits in unconditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments. For eligible projects, the interactive HVAC demand savings is a fixed percentage set at 10% of the lighting demand savings. Similarly, the interactive HVAC energy savings is fixed and equal to 5% of the lighting energy savings. A Project Sponsor may propose and demonstrate electric energy and demand savings for evaporative or gas air conditioning systems using a full measurement and verification approach.

1.2.3.1 Peak Demand Savings

Equation 1.1:

Connected Lighting Load Reduction [kW] =	**Pre Lighting Demand [kW] – Post Lighting Demand [kW]**

Equation 1.2:

Interactive HVAC Demand Savings [kW] =	**Connected Lighting Load Reduction [kW] * 0.10**

Equation 1.3:

Total Demand Savings [kW] =	**(Connected Lighting Load Reduction [kW] + Interactive HVAC Demand Savings [kW]) * Coincidence Factor**

1.2.3.2 Energy savings

Equation 1.4:

Lighting Energy Savings [kWh] =	**Connected Lighting Load Reduction [kW] * Annual Operating Hours [hrs]**

Equation 1.5:

Interactive HVAC Energy Savings [kWh] =	**Lighting Energy Savings [kWh] * 0.05**

Equation 1.6:

Total Energy Savings [kWh]	**=**	**Lighting Energy Savings [kWh] + Interactive HVAC Energy Savings [kWh]**

1.2.4 Example

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

Example[1]

A lighting efficiency project is proposed for a typical small office building. The Project Sponsor submits the Lighting Inventory survey forms as part of the Final Application detailing the existing and proposed equipment. The table below summarizes the existing and proposed connected lighting load for each usage group[2] in the project. The CF for office buildings is **80%**.

Area Description	Survey[2] Lines	Connected Lighting Load (kW)			Stipulated Operating Hours	Annual kWh Savings	Actual kW Savings
		Existing	Proposed	Difference			
Hallways and Stairs	20	3.6	2.0	1.6	3,760	6,016	1.3
Common Offices	72	66.0	14.4	51.6	3,760	194,016	41.3
Conference Rooms	20	15.6	9.6	6.0	3,760	22,560	4.8
Exit Signs	24	6.0	4.8	1.2	3,760	4,512	1.0
Private Offices	44	59.2	41.2	18.0	3,760	67,680	14.4
Restrooms	20	4.0	2.8	1.2	3,760	4,512	1.0
Total	**200**	**154.4**	**74.8**	**79.6**		**299,296**	**63.7**

Based on the collected data, the demand and energy savings are calculated:

(a) Connected Lighting Load Reduction = 154.4 kW – 74.8 kW
= 79.6 kW.

(b) Interactive HVAC Demand Savings = 79.6 kW * 0.10
= 8.0 kW.

(c) Total Demand Savings = (79.6 kW + 8.0 kW) * 0.80
= 70.1 kW.

(d) Lighting Energy Savings = 79.6 kW * 3,760 hours
= 299,296 kWh.

(e) Interactive HVAC Energy Savings = 299,296 kWh * 0.05
= 14,965 kWh.

(f) Total Energy Savings = 299,296 kWh + 14,965 kWh
= 314,261 kWh.

[1] Projects that consist of only lighting measures receive 65% of the total incentive.
[2] For a description of *Usage Groups* and *Survey Lines*, see Section 1.3 to follow.

1.3 Metered Hours Method

The **Metered Hours Method** involves monitoring a statistically significant sample of fixtures to determine post-installation operating hours. This involves developing a sampling plan to monitor the average operating hours for each lighting usage group. The Project Sponsor should conduct all meter installation, retrieval and data analysis.

1.3.1 Pre-installation M&V Activities

1.3.1.1 Pre-installation equipment survey

Prior to installing the lighting retrofit, the Project Sponsor conducts a pre-installation equipment survey, to be submitted as part of the Final Application. The purpose of the pre-installation equipment survey is to inventory all existing lighting equipment, and to propose the replacement equipment to be installed. Surveys shall include all baseline lighting fixtures and controls, regardless of whether they will be retrofitted. Fixture wattages should be based on the Table of Standard Fixture Wattages. This information should be organized by usage group and tabulated electronically in the Lighting Equipment Survey (see Chapter 9 of the Project Sponsor's Manual for an explanation).

Non-operating fixtures

For non-operating fixtures, the baseline demand may be adjusted by using values from the Table of Standard Fixture Wattages. **The number of non-operating fixtures will be limited to 10% of the total fixture count per facility**. If, for example, more than 10% of the total number of fixtures is inoperative, the number of fixtures beyond 10% will be assumed to have baseline fixture wattage of zero. Thus the total baseline demand for the project will be adjusted accordingly.

Usage groups

When performing the pre-installation activities associated with this M&V approach, Project Sponsors should organize the equipment into **usage groups**—collections of equipment (e.g., rooms with lighting fixtures) with similar operating schedules and functional uses. For instance, although a site's open office lighting may have the same annual hours of operation as the private office lighting, the two have different functional uses. In this case, a change in the operating hours of the private office lights due to the installation of an occupancy sensor would not be relevant to the operating hours of the open office lights. Please refer to Table 1.2 to determine the recommended minimum number of usage groups for the project site type.

Table 1.2: Suggested minimum numbers of Usage Groups for project site types

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

1.3.1.2 Pre-installation inspection

EPE or its contractor will conduct a pre-installation inspection to verify that the Project Sponsor has properly documented the baseline. The criterion for baseline acceptance is that the installed demand must be within ±5% of the demand reported on the lighting survey form. If the error exceeds ±5%, the Project Sponsor is allowed to resubmit corrected lighting tables. If the project fails inspection twice due to incorrect survey forms, the Project Sponsor will bear the cost of subsequent inspections. The cost for each subsequent inspection will be $288. Total costs for all subsequent inspections will be deducted from the incentive amount paid to the Project Sponsor.

The operating hours of the baseline lighting system are assumed to be the same as those of the post-retrofit lighting system and are not measured as part of the pre-installation M&V activities.

1.3.2 Post-installation M&V Activities

1.3.2.1 Post-installation equipment survey

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

1.3.2.2 Post-installation inspection

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

1.3.2.3 Post-Installation operating hours

After the lighting retrofit has been installed, the Project Sponsor conducts short-term metering of the operating hours for a random sample of fixtures in each usage group. As part of the FA review and approval, EPE or their contractor can assist the Project Sponsor to randomly select the population of fixtures to be metered.

Metering requirements

For facilities with little variation in weekly operating schedules (such as offices), monitoring shall be conducted for each selected circuit for a recommended minimum of **two to four weeks** during the entire year. Monitoring should not be installed during significant holidays or vacations. If a holiday or vacation falls within the monitoring period, the duration should be extended for as many days as that holiday or vacation. For facilities such as schools, where operating hours vary seasonally, monitoring should be conducted for a minimum period during each season (i.e., in-session [fall], and out-of-session [summer]). In these cases, one of the monitoring periods should depict typical performance during the EPE peak demand period.

A *Survey line*, or last point of control (LPC), is a distinct portion of an electrical circuit serving a set of equipment that is controlled on a single switch. So if a project involves a *Hallway and Stairs* usage group that has 20 survey lines or LPCs, such as the previous *Example* in Section 1.2.4, it means there are 20 separate circuits in those like areas controlled at a switch (Two or more switches controlling the same circuit would still be just one survey line).

The required sample size given for each usage group in Table 1.3 then is the number of circuits within a distinct usage group that would need to be monitored that year or metering period to ensure a good representative sample. Note that, because light loggers sometimes fail, over-sampling is strongly recommended. Light loggers should be tested and calibrated prior to installation to verify that the light loggers are functioning properly.

Table 1.3: Monitoring sample sizes*

Population of Survey Lines in Usage Group (n)	Sample Size
n≤4	All
5	4
6≤n<9	5
9≤n<14	6
14≤n<20	7
20≤n<34	8
34≤n<68	9
68≤n<386	10
n≥386	11

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

Calculation of average operating hours

The Project Sponsor should extrapolate results from the monitored sample to the population to calculate the average lighting operating hours for every unique usage group. Simple, unweighted averages of operating hours should be calculated for each usage group using Equation 1.7. The Project Sponsor should use these average operating hours to calculate the energy savings for each respective usage group.

Equation 1.7: Calculation of annual operating hours for a usage group

$$Hours_{annual,u} = \frac{\sum_{i=1}^{n}\left[\frac{Hours_{on,i}}{Hours_{metered,i}} * 8{,}760\ {}^{hours}\!/\!_{year}\right]}{n}$$

Where:

$Hours_{annual,u}$	=	Average annual operating hours for usage group *u*
$Hours_{on,i}$	=	Operating hours observed during the metering period for circuit *i*
$Hours_{metered,I}$	=	Total number of hours in the metering period for circuit *i*
N	=	Number of metered circuits in usage group *u*

Similarly, Equation 1.8 illustrates the calculation of average on-peak demand coincidence factor (CF) for a usage group. The CF multiplied by the difference in baseline and post-installation demand for each usage group, determined from the Table of Standard Fixture Wattages, gives the calculated demand savings. Demand savings are only allowed for lighting fixtures that will be in operation on weekdays between the hours of 1 PM and 7 PM during the months of May through September.

Equation 1.8: Calculation of coincidence factor for a usage group

$$CF_u = \frac{\sum_{i=1}^{n}\left[\frac{Hours_{peak\,on,i}}{Hours_{peak\,metered,i}}\right]}{n}$$

Where:

CF_u	=	Peak demand coincidence factor for usage group *u*
$Hours_{peak\ on,i}$	=	Equipment on-hours observed during the EPE peak demand period during the metering period for circuit *i*
$Hours_{peak\ metered,i}$	=	Total number of EPE peak demand hours in the metering period for circuit *i*
N	=	Number of metered circuits in usage group *u*

1.3.3 Calculation of Demand and Energy Savings

The peak demand savings and energy savings are calculated according to Equations 1.1 through 1.6 in Sections 1.2.3.1 and 1.2.3.2, and Equations 1.9 and 1.10 below. The hours of operation should be calculated for each usage group and also for each season in which the usage groups' operating hours may vary (as for schools). The annual hours of operation are determined by adding together the operating hours that are calculated for each season. If the operating hours do not vary seasonally, use one year as the "season". Interactive HVAC demand and energy savings may be calculated using deemed savings multipliers only for lighting retrofits taking place in spaces air-conditioned with electric refrigerated air systems. Lighting retrofits in unconditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments. For eligible projects, the interactive HVAC demand savings is a fixed percentage set at 10% of the lighting demand savings. Similarly, the interactive HVAC energy savings is fixed and equal to 5% of the lighting energy savings. A Project Sponsor may propose and demonstrate electric energy and demand savings for evaporative or gas air conditioning systems using a full measurement and verification approach.

1.3.3.1 Hours of Operation (see Equation 1.7 above)

Equation 1.9:

$$\text{Seasonal Hours of Operation [hrs]} = \frac{\text{Hours Lights On}}{\text{Hours Lights Metered}} * \text{Hours in Season}$$

Equation 1.10:

$$\text{Annual Hours of Operation [hrs]} = \text{Sum of } \{\text{Seasonal Hours of Operation [hrs]}\}$$

1.3.3.2 Peak demand savings

Peak demand savings are calculated using Equations 1.1, 1.2, and 1.3 in Section 1.2.3.1.

1.3.3.3 Energy savings

Energy savings are calculated using Equations 1.4, 1.5, and 1.6 in Section 1.2.3.2.

1.3.4 Example

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

Example[3]

A lighting efficiency project is proposed for a small, non-24-hour retail store. The Project Sponsor submits the Lighting Equipment Survey as part of the Final Application detailing the existing and proposed equipment inventory. The following table summarizes the existing and proposed connected lighting load (including calculated Coincidence Factors) for each usage group in the project, as well as the metering results and annual savings.

In this example, the operating hours are metered according to the required sample size for each usage group in the project. Because there is only one operating season, 13 light loggers are installed for one three-week period. The operating hours for each usage group are the average of observed operating hours from all meters. Using equations (a) through (g), the energy savings for *Receiving* will be

(a) $\text{Annual Operating Hours [hrs]} = \left\{ \left[\frac{410}{504} \right] * 8{,}760 \right\}$ **= 7,126 [hrs]**

(b) Lighting Demand Savings [kW] = 9.7 [kW] – 5.4 [kW] **= 4.3 [kW]**

(c) Interactive HVAC Demand Savings [kW] = 4.3 [kW] * 0.10 **= 0.4 [kW]**

(d) Total Demand Savings [kW] = {4.3 [kW] + 0.4 [kW]} * 0.82 **= 3.9 [kW]**

(e) Lighting Energy Savings [kWh] = 4.3 [kWh] * 7126 [hrs] **= 30,642 [kWh]**

(f) Interactive HVAC Energy Savings [kWh] = 30,642 [kWh] * 0.05 **= 1,532 [kWh]**

(g) Total Energy Savings [kWh] = 30,642 [kWh] + 1,532 [kWh] **= 32,174 [kWh]**

The energy savings is then calculated for each usage group.

	Equation Solutions						
Usage Group	(a)	(b)	(c)	(d)	(e)	(f)	(g)
Receiving	***7,126***	***4.3***	***0.4***	***3.9***	***30,642***	***1,532***	***32,174***
Continuous	8,760	0.2	0.0	0.2	1,752	88	1,840
Admin. Offices	3,024	0.6	0.1	0.5	1,814	91	1,905
Restrooms	2,120	0.5	0.1	0.5	1,060	53	1,113
Sales Floor	5,840	13.3	1.3	10.8	77,672	3884	81,556
Total				**15.9**			**118,588**

[3] Projects that consist of only lighting receive 65% of the total incentive.

2 M&V Guidelines for Lighting Efficiency Measures with Controls

2.1 Overview

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

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

Changes in lighting load are determined using lighting fixture wattage values indicated in the Table of Standard Fixture Wattages.

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

> **Stipulated Control Savings Method** – Use stipulated operating hours and Coincidence Factor (CF), depending on building type. Use a stipulated Power Adjustment Factor (PAF) depending on type of lighting control (see Section 2.2 of this chapter).
>
> **Full M&V Method for Lighting Controls** – Meter pre- and/or post-installation operating hours using defined sampling techniques (see Section 2.3 of this chapter). Calculate the CF from metered data.

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

Interactive demand and energy savings due to the reduction of lighting load on cooling equipment are stipulated. Interactive HVAC demand and energy savings may be calculated using deemed savings multipliers <u>only</u> for lighting retrofits taking place in spaces air-conditioned with electric refrigerated air systems. Lighting retrofits in unconditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments. For eligible projects, the interactive HVAC demand savings is a fixed percentage set at 10% of the lighting demand savings. Similarly, the interactive HVAC energy savings is fixed and equal to 5% of the lighting energy savings. A Project Sponsor may propose and demonstrate electric energy and demand savings for evaporative or gas air conditioning systems using a full measurement and verification approach

In addition to determining operating hours, the Project Sponsor is required to conduct pre- and post-installation equipment surveys. The Project Sponsor should fill out and submit survey results in the standard Lighting Equipment Survey using fixture codes provided in the Table of Standard Fixture Wattages. Refer to Chapter 9 (Final Application) of the Project Sponsor's Manual for an explanation of the Lighting Equipment Survey. EPE or its contractor will conduct pre- and post-installation inspections to verify the reported baseline and retrofit conditions, respectively.

2.2 Stipulated Control Savings Method

This method requires the use of the appropriate stipulated hours from Table 2.1 and a PAF from Table 2.2. If values from these tables do not accurately characterize the building type and operation, then the Project Sponsor should refer to the *Full M&V Method for Lighting Controls* in Section 2.3 of this chapter for an appropriate M&V technique.

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

Building Type	Stipulated Annual Operating Hours	Avg. On-Peak Demand Coincidence Factor	Interactive HVAC Demand Savings	Interactive HVAC Energy Savings
24-Hour Supermarket/Retail	6,900	95%	10%	5%
College/University	2,085	67%	10%	5%
Education (K-12; no summer session)	2,150	82%	10%	5%
In-Patient Health Care	3,750	60%	10%	5%
Multi-Family Housing, Common Areas[1]	4,772	87%	10%	5%
Non 24-Hour Supermarket/Retail/Restaurant	4,250	95%	10%	5%
Office	3,760	80%	10%	5%
Parking Structure[1]	7,884	100%	0%	0%

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

Table 2.2: Power Adjustment Factors (PAFs)*

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

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

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

2.2.1 Pre-Installation M&V Activities

2.2.1.1 Pre-installation equipment survey

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

Non-operating fixtures

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

2.2.1.2 Pre-installation inspection

EPE or its contractor will conduct a pre-installation inspection to verify that the Project Sponsor has properly documented the baseline. The criterion for baseline acceptance is that the installed demand must be within ±5% of the demand reported on the lighting survey form. If the error exceeds ±5%, the Project Sponsor is allowed to resubmit corrected lighting tables. If the project fails inspection twice due to incorrect survey forms, the Project Sponsor will bear the cost of subsequent inspections. The cost for each subsequent inspection will be $288. Total costs for all subsequent inspections will be deducted from the incentive amount paid to the Project Sponsor.

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

2.2.2 Post-Installation M&V Activities

2.2.2.1 Post-Installation equipment survey

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

2.2.2.2 Post-installation inspection

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

2.2.2.3 Operating hours

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

2.2.3 Calculation of Demand and Energy Savings

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

Interactive HVAC demand and energy savings may be calculated using deemed savings multipliers only for lighting retrofits taking place in spaces air-conditioned with electric refrigerated air systems. Lighting retrofits in unconditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments. For eligible projects, the interactive HVAC demand savings is a fixed percentage set at 10% of the lighting demand savings. Similarly, the interactive HVAC energy savings is fixed and equal to 5% of the lighting energy savings. A Project Sponsor may propose and demonstrate electric energy and demand savings for evaporative or gas air conditioning systems using a full measurement and verification approach.

2.2.3.1 Peak demand savings

Equation 2.1:

Connected Lighting Load Reduction [kW]	**=**	**Pre Lighting Demand [kW] – Post Lighting Demand [kW]**

Equation 2.2:

Interactive HVAC Demand Savings [kW]	**=**	**Connected Lighting Load Reduction [kW] * 0.10**

Equation 2.3:

Total Demand Savings [kW]	**=**	**(Connected Lighting Load Reduction [kW] + Interactive HVAC Demand Savings [kW]) * Coincidence Factor**

2.2.3.2 Energy savings

Equation 2.4:

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

Equation 2.5:

Interactive HVAC Energy Savings [kWh]	**=**	**Lighting Energy Savings [kWh] * 0.05**

Equation 2.6:

Total Energy Savings [kWh]	**=**	**Lighting Energy Savings [kWh] + Interactive HVAC Energy Savings [kWh]**

2.2.4 Example

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

Example*

A lighting efficiency and controls project is proposed for a typical small office building. Controls are to be installed in some common offices and private offices. The Project Sponsor submits the lighting survey detailing the existing and proposed equipment inventory. The following table summarizes the existing and proposed connected lighting load and operating hours for each usage group in the project. For office buildings, the stipulated operating hours is 3760 hrs and the CF is **80%**.

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

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

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

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

(a) Connected Lighting Load Reduction [kW] = 9.0 [kW] – 4.3 [kW] **= 4.7 [kW]**

(b) Interactive HVAC Demand Savings [kW] = 4.7 [kW] * 0.10 **= 0.5 [kW]**

(c) Total Demand Savings [kW] = (4.7 [kW] + 0.5 [kW]) * 0.80 **= 4.2 [kW]**

(d) Lighting Energy Savings [kWh] = {9.0 [kW] – 4.3 [kW]} * 3760 [hrs] * 0.8 **= 14,138 [kWh]**

(e) Interactive HVAC Energy Savings [kWh] = 14,138 [kWh] * 0.05 **= 707 [kWh]**

(f) Total Energy Savings [kWh] = 14,138 [kWh] + 707 [kWh] **= 14,845 [kWh]**

The energy savings is then calculated for each usage group.

Results

Area Description	(a)	(b)	(c)	(d)	(e)	(f)
Common Offices w/ Controls	***4.7***	***0.5***	***4.2***	***14,138***	***707***	***14,845***
Common Offices	6	0.6	5.3	22,560	1,128	23,688
Private Offices	3.1	0.3	2.7	11,656	583	12,239
Private Offices w/ Controls	2.3	0.2	2.0	6,054	303	6,357
Conference Rooms	2.4	0.2	2.1	9,024	451	9,475
Restrooms	0.2	0	0.2	752	38	789
Total			**16.5**			**67,393**

2.3 Full M&V Method for Lighting Controls

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

Interactive demand and energy savings due to the reduction of lighting load on cooling equipment are stipulated. Interactive HVAC demand and energy savings may be calculated using deemed savings multipliers only for lighting retrofits taking place in spaces air-conditioned with electric refrigerated air systems. Lighting retrofits in unconditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments. For eligible projects, the interactive HVAC demand savings is a fixed percentage set at 10% of the lighting demand savings. Similarly, the interactive HVAC energy savings is fixed and equal to 5% of the lighting energy savings. A Project Sponsor may propose and demonstrate electric energy and demand savings for evaporative or gas air conditioning systems using a full measurement and verification approach.

2.3.1 Pre-installation M&V Activities

2.3.1.1 Pre-installation equipment survey

Prior to installing the lighting retrofit, the Project Sponsor conducts a pre-installation equipment survey, to be submitted as part of the FA. The purpose of the pre-installation equipment survey is to inventory all existing lighting equipment, and to propose the replacement equipment to be installed. Surveys shall include all baseline lighting fixtures and controls, regardless of whether they will be retrofitted. Fixture wattages should be based on the Table of Standard Fixture Wattages. This information should be organized by usage group and tabulated electronically in the Lighting Equipment Survey (see Chapter 9 of the Project Sponsor's Manual for an explanation).

Non-operating fixtures

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

Usage groups

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

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

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

Metering Requirements

For facilities with little variation in weekly operating schedules (such as offices), monitoring should be conducted for each selected circuit for a recommended minimum of **two to four weeks** during the entire year. Monitoring should not occur during significant holidays or vacations. If a holiday or vacation falls within the monitoring period, the duration should be extended for as many days as that holiday or vacation. For facilities such as schools, where operating hours vary seasonally, monitoring should be conducted for a minimum period during each season (i.e., in-session [fall], and out-of-session [summer]).

A *Survey line*, or last point of control (LPC), is a distinct portion of an electrical circuit serving a set of equipment that is controlled on a single switch. So if a project involves a usage group that has 20 survey lines or LPCs, it means there are 20 separate circuits in those like areas controlled at a switch (Two or more switches controlling the same circuit would still be just one survey line).

Table 2.4 shows the required minimum number of circuits to randomly sample depending on a usage group's survey line population; note that, because lighting loggers sometimes fail, over-sampling is strongly recommended. Light loggers should be tested and calibrated prior to installation to verify that the light loggers are functioning properly.

Table 2.4: Metering sample sizes*

Population of Survey Lines in Usage Group (n)	Sample Size
n≤4	All
5	4
6≤n<9	5
9≤n<14	6
14≤n<20	7
20≤n<34	8
34≤n<68	9
68≤n<386	10
n≥386	11

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

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

2.3.1.2 Pre-installation inspection

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

2.3.1.3 Monitoring of pre-installation hours

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

2.3.2 Post-installation M&V Activities

2.3.2.1 Post-Installation equipment survey

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

2.3.2.2 Post-installation inspection

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

2.3.2.3 Post-installation operating hours

The Project Sponsor should determine the post-installation operating hours by monitoring a statistically significant sample of fixtures as documented and verified in the IR. The Project Sponsor should develop a sampling plan to monitor the average operating hours of a sample of fixtures in each usage group, <u>both with and without controls</u>. The required usage group sampling sizes and metering requirements, and equations for calculating average operating hours (Equation 1.7) and CF (Equation 1.8), are defined under *Metering Requirements* in Section 1.3.2.3.

2.3.3 Calculation of Demand and Energy Savings

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

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

Equation 2.7:

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

Equation 2.8:

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

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

Equation 2.9:

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

Equation 2.10:

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

2.3.3.3 Peak Demand Savings

Equation 2.11:

Connected Lighting Load Reduction [kW] = Pre Lighting Demand [kW] – Post Lighting Demand [kW]

Equation 2.12:

Interactive HVAC Demand Savings [kW] = Connected Lighting Load Reduction [kW] * 0.10

Equation 2.13: (See Equation 1.8 for Coincidence Factor calculation)

Total Demand Savings [kW] = (Connected Lighting Load Reduction [kW] + Interactive HVAC Demand Savings [kW]) * Coincidence Factor

2.3.3.4 Energy savings

Equation 2.14:

Lighting Energy Savings [kWh] = {Pre Lighting Demand [kW] * Pre Annual Operating Hours} – {Post Lighting Demand [kW] * Post Annual Operating Hours}

Equation 2.15:

Interactive HVAC Energy Savings [kWh] = Lighting Energy Savings [kWh] * 0.05

Equation 2.16:

Total Energy Savings [kWh] = Lighting Energy Savings [kWh] + Interactive HVAC Energy Savings [kWh]

Example

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

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

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

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

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

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

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

(c) Connected Lighting Load Reduction [kW] = 45.0 [kW] – 21.5 [kW] **= 23.5 [kW]**

(d) Interactive HVAC Demand Savings [kW] = 23.5 [kW] * 0.10 **= 2.4 [kW]**

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

(f) Lighting Energy Savings [kWh] = 45.0 [kW] * 7,821 [hrs] – 21.5 [kW] * 3511 [hrs]

= 276,459 [kWh]

(g) Interactive HVAC Energy Savings [kWh] = 276,459 [kWh] * 0.05 **= 13,823 [kWh]**

(h) Total Energy Savings [kWh] = 276,459 [kWh] + 13,823 [kWh] **= 290,282 [kWh]**

The energy savings are then calculated for each usage group.

Equation Solutions

Usage Groups	**(a)**	**(b)**	**(c)**	**(d)**	**(e)**	**(f)**	**(g)**	**(h)**
Common Offices	-	7,821	30.0	3.0	27.1	234,630	11,732	246,362
Common Offices w/Controls	***7,821***	***3,511***	***23.5***	***2.4***	***19.4***	***276,459***	***13,823***	***290,282***
Private Offices	-	3,945	15.5	1.6	13.3	61,148	3,057	64,205
Private Offices w/Controls	5,214	3,563	11.5	1.2	6.8	76,471	3,824	80,295
Conference Rooms	-	2,764	12.0	1.2	7.1	33,168	1,658	34,826
Misc. Facilities	-	2,555	4.5	0.5	3.6	11,498	575	12,073
Continuous	-	8,708	3.5	0.4	3.9	30,478	1,524	32,002
Restrooms	-	2,346	1.0	0.1	1.0	2,346	117	2,463
Restrooms w/Controls	8,343	2,729	2.0	0.2	1.5	25,107	1,255	26,362
Total					**83.8**	**751,305**		**788,870**

3 M&V Guidelines for Replacement of Cooling Equipment

3.1 Overview

Cooling equipment retrofits involve the replacement of the existing equipment with high-efficiency equipment. This chapter presents both a deemed savings approach and a simplified approach to the measurement and verification of savings from the retrofit of cooling equipment. In general, the measurement and verification (M&V) methods described in this chapter can be used for projects involving the one-for-one change-out of cooling equipment. Potential qualifying equipment includes:

- Unitary air conditioners (DX, air-cooled, evaporative, or water-cooled)
- Heat pumps (air-cooled, evaporative, or water-cooled)
- Chillers (air-cooled centrifugal, water-cooled centrifugal, air-cooled screw, etc.)
- Compressors (centrifugal, screw, reciprocating)
- Fuel switching from electric to gas-driven cooling equipment

The retrofits must have the following characteristics:

- The newly installed electric cooling equipment capacity must be within **80%** to **120%** of the replaced electric cooling equipment capacity.
- No additional measures are being installed that directly affect the operation of the cooling equipment (i.e., control sequences, cooling towers, condensers).

If the proposed retrofit does not meet these requirements, refer to the Full M&V guidelines presented in Chapters 7, 8, and 9 for appropriate M&V techniques.

The baseline efficiency used in the savings calculation is based on ASHRAE Standard 90.1-1989. Efficiency values from this standard can be found in the Standard Cooling Equipment Tables under the heading "Baseline Performance Standard", Appendix A of the *Appendices to M&V Guidelines* found at the end of this document.

3.2 Deemed Savings for Cooling Equipment

The *deemed savings* approach to M&V for cooling equipment is applicable to both one-for-one equipment replacement as well as equipment replacement involving a change in equipment type, e.g. changing from air-cooled DX units to a water-cooled chiller.

Projects that are eligible to use the deemed savings approach meet the following requirements:

- The existing and proposed cooling equipment are electric.

- The Project Sponsor and EPE agree on the correct climate zone to use for the calculation.
- Coefficients are listed in Table A.10 for the type of building in which the retrofit occurs and the type of equipment involved.
- The building falls into one of the categories described in Table 3.1.

Table 3.1: Building descriptions for use in the air-conditioning equipment deemed savings M&V methodology

Building Type	Description
Religious Worship	A religious worship building that experiences full operation on Sundays, and a partial schedule on weekdays and Saturdays.
College	A multi-story college building that operates a full day five days per week and a partial day on weekends.
Convenience	A small convenience store that operates 24 hours per day, 7 days per week.
Fast-Food	A small fast food restaurant that operates a full day, seven days per week. Generally smaller than 3,000 sq. ft.
Grocery	Typical supermarket that operates between 16 and 24 hours per day, 7 days per week.
Hospital	A multi-story hospital building that operates 24 hours per day, 7 days per week.
Hotel	A typical multi-story hotel that operates 24 hours per day, 7 days per week. Usually larger than 50,000 sq. ft.
Motel	A low-rise motel that operates 24 hours per day, 7 days per week. Usually smaller than 50,000 sq. ft.
Nursing Home	An assisted care facility that operates 24 hours per day, 7 days per week.
Office, Large	Typical multi-story office building that operates 12 to 16 hours per day, Monday through Friday, a half day on Saturday and a few hours on Sunday. Applicable for buildings greater than 50,000 sq. ft.
Office, Small	Typical low-rise office building that is operated mostly Monday through Friday and a minimal number of hours on Saturday and Sunday. Applicable for buildings up to 50,000 sq. ft.
Public Assembly	A large public assembly building that operates on a partial schedule all days.
Retail	Retail store that operates typical business hours Monday through Saturday and a reduced day on Sundays.
Restaurant	Typical small restaurant operating full day six days per week with a reduced schedule on Sundays. Generally larger than 3,000 sq. ft.
School	A low-rise elementary or high school that operates all day Monday through Friday, 50 weeks per year.
Service	A light commercial building that operates a full day six days per week. Examples include beauty parlors, automotive shops and so on.
Warehouse, Non-Refrig.	A conditioned warehouse, not refrigerated, that operates 24 hours/ day, 7 days per week.

Table A.10 does not list coefficients for every type of cooling equipment in every building type. For example, the deemed savings M&V approach is not available for water-cooled chillers for small building types such as convenience stores and fast food restaurants because water-cooled chillers are uncommon in these types of buildings.

3.2.1 Pre-Installation M&V Activities

3.2.1.1 Pre-installation Site Survey

The goals of the pre-installation site survey are to identify the cooling equipment and establish the baseline efficiency. The information collected should include: equipment type, year, make/model, rated capacity, rated efficiency.

The baseline efficiency is determined by comparing the rated efficiency of the existing unit to the minimum efficiency listed in the Standard Cooling Equipment Table, which are based on ASHRAE 90.1-1999, provided in Appendix A. The baseline efficiency is equal to the more efficient of the two values.

3.2.1.2 Pre-installation Inspection

EPE or its contractor will conduct a pre-installation inspection to verify that the Project Sponsor has properly documented the baseline in the FA. **Demolition or removal of existing equipment and/or installation of new equipment cannot commence until the pre-installation inspection is completed and EPE has issued the Project Authorization**

3.2.1.3 Pre-installation Performance Monitoring

The simplified M&V procedure for electric-to-electric cooling equipment replacements does not require pre-installation monitoring of existing equipment. The existing equipment efficiency is determined from the Standard Cooling Equipment Tables, Appendix A. The existing equipment load and operating schedule are assumed to be the same as those of a typical facility in a specific building type group.

3.2.2 Post-Installation M&V Activities

3.2.2.1 Post-installation Equipment Survey

Once the new equipment retrofit is complete, the Project Sponsor conducts and submits a post-installation equipment survey as part of the Installation Report (IR). The survey should include: installed equipment type, year, make/model, rated capacity, and rated efficiency. The cooling equipment description and its location should be included with the IR submittal.

The Project Sponsor must submit manufacturer's documentation of the rated efficiency of all newly installed cooling equipment, based upon ARI test conditions. This documentation will be in the form of manufacturer cut sheets or factory performance test results that document the part load performance of the equipment.

3.2.2.2 Post-installation Inspection

EPE or its contractor will conduct a post-installation inspection to verify that the equipment was installed as reported and is documented accurately.

3.2.3 Deemed Savings Calculations

The deemed savings methodology involves the application of two mathematical equations shown in Equation 3.3 and Equation 3.4.

Equation 3.1: Calculation of peak demand savings for cooling equipment

$$kW_{\text{savings}} = Tons * (a \cdot \eta_{\text{baseline}} - b \cdot \eta_{\text{post-installation}})$$

Where:

kW_{savings}	=	Calculated demand savings
$Tons$	=	The rated equipment cooling capacity at ARI standard conditions
a	=	The demand coefficient from Table A.10 in the Appendix for the appropriate climate zone, building type and baseline equipment type.
η_{baseline}	=	Efficiency of the baseline equipment (kW/Ton)
b	=	The demand coefficient from Table A.10 in the Appendix for the appropriate climate zone, building type and retrofit equipment type.
$\eta_{\text{post-installation}}$	=	Rated efficiency of the installed equipment (kW/Ton)

Equation 3.2: Calculation of energy savings for cooling equipment

$$kWh_{savings} = Tons * (c \cdot \eta_{baseline} - d \cdot \eta_{post\text{-}installation})$$

Where:

$kWh_{savings}$	=	Calculated energy savings
$Tons$	=	The rated equipment cooling capacity at ARI standard conditions
c	=	The energy coefficient from Table A.10 in the Appendix for the appropriate climate zone, building type and baseline equipment type.
$\eta_{baseline}$	=	Efficiency of the baseline equipment (kW/Ton)
d	=	The energy coefficient from Table A.10 in the Appendix for the appropriate climate zone, building type and retrofit equipment type.
$\eta_{post\text{-}installation}$	=	Rated efficiency of the installed equipment (kW/Ton)

To calculate savings for cooling equipment retrofits using the deemed savings methodology, follow these steps:

1. Determine the applicable baseline efficiency for the existing equipment in kW/ton ($\eta_{baseline}$). Record either the minimum baseline efficiency (ASHRAE 90.1-1999), or the actual full load rated efficiency if it is better than ASHRAE 90.1-1999.

   Use the following conversions to get kW/Ton where necessary [5]:

   kW/ton = 12 / EER

   kW/ton = 3.516 / COP

   kW/ton = 12 / (SEER*0.697 + 2.0394)

2. Determine the applicable efficiency for the new equipment in kW/ton ($\eta_{post\text{-}installation}$).
3. Determine the applicable equipment capacity (*Tons*). Record the lesser of the existing unit tonnage or the replacement unit tonnage.
4. Determine the applicable demand and energy coefficients (*a, b, c,* and *d*). Go to the Table A.10 in Appendix A. Look up the demand and energy coefficients for the appropriate building and equipment type.
5. Use equations 3.1 and 3.2 to calculate peak demand and energy savings.

[5] The conversion from SEER to kW/ton is an approximation based on published data from the Carrier Corporation

Example

A 150-ton air-cooled packaged unit in a retail application is a more efficient unit (than required by current energy codes).

Step 1 The Project Sponsor finds the appropriate baseline efficiency from Appendix A, Table A.6. A 150-ton air-cooled packaged unit has an EER of 8.2. Using the conversion, kW/Ton = 12/EER, the Project Sponsor finds that η_{baseline} = 1.463 kW/Ton.

Step 2 The manufacturer's data for the new equipment shows that the EER = 10.0. Using the conversion, kW/Ton = 12/EER, the Project Sponsor finds that $\eta_{\text{post-installation}}$ = 1.200 kW/Ton.

Step 3 The new packaged unit is a 150-ton unit.

Step 4 The Project Sponsor looks in Appendix A, Table A.10 to find the appropriate coefficients. The demand coefficient for a retail building with a DX air-cooled unit in El Paso is 0.92, so $a = b$ = 0.92. The energy coefficient for a retail building with a DX air-cooled unit is 2,225, so $c = d$ = 2,225.

Step 5 By inserting the information gathered in Steps 1-4 into Equations 3.1 and 3.2, the Project Sponsor calculates the savings:

$kW_{savings}$ = 150* (0.92*1.463-0.92*1.200) = 48.4 kW

$kWh_{savings}$ = 150* (2,225*1.463-2,225*1.200) = 117,035 kWh

In some cases where a piece of cooling equipment is replaced with a different type of cooling equipment, adjustments must be made to the savings calculations. The replacement of an air-cooled machine with a water-cooled machine is an example. In this case, the savings calculations must consider the additional auxiliary loads for the condenser water pump and the cooling tower fan. Energy and peak demand savings will need to be adjusted downward to account for the peak demand and energy consumption of the auxiliary equipment. The next example, below, provides an illustration of the required calculation. The Project Sponsor must include information about the auxiliary equipment in the required SOP submittals.

Example

A 200 ton air-cooled chiller with condenser is replaced with a water-cooled chiller of the same size in a large office building in El Paso.

Step 1 The Project Sponsor finds the appropriate baseline efficiency from Appendix A, Table A.7. A 200-ton air-cooled chiller with condenser has a COP = 2.50. Using the conversion, kW/ton = 3.516 / COP, the Project Sponsor finds that η_{baseline} = 1.407kW/Ton.

Step 2 The manufacturer's data for the new equipment shows that the COP = 4.0. Using the conversion, kW/ton = 3.516 / COP, the Project Sponsor finds that $\eta_{\text{post-installation}}$ = 0.879 kW/Ton.

Step 3 The existing and new chillers are each 200-ton units.

Step 4 The Project Sponsor looks in Appendix A, Table A.10 to find the appropriate coefficients. The demand coefficient for a large office building with an air-cooled chiller in El Paso is 0.88, so a = 0.88 The demand coefficient for a large office building with a water-cooled chiller in El Paso is 0.80, so b = 0.80. The energy coefficient for a large office building with air-cooled chiller in El Paso is 2,232, so c = 2,232. The energy coefficient for a large office building with a water-cooled chiller in El Paso is 2,406, so d = 2,406.

Step 5 By inserting the information gathered in Steps 1-4 into Equations 3.1 and 3.2, the Project Sponsor calculates the savings:

$$kW_{savings,GROSS} = 200 * (0.88 * 1.407 - 0.80 * 0.879) = 107\ \text{kW}$$

$$kWh_{savings,GROSS} = 200 * (2{,}232 * 1.407 - 2{,}406 * 0.879) = 205{,}110\ \text{kWh}$$

Extra Step: Additional Adjustments for Auxiliary Equipment The equipment efficiency for the air-cooled chiller includes the condenser fans, but the equipment efficiency for the water-cooled chiller does not include the condenser water pump and cooling tower. Therefore, the savings must be reduced to account for the peak demand and energy consumption of the water-cooled system's additional equipment. Assuming a 5 hp condenser pump and a 5 hp cooling tower fan is added as a part of the retrofit, the kW and kWh savings are reduced as follows:

$$kW_{\text{CW pump and CT fan}} = (5+5)\text{hp} * .746\ \text{kW/hp} \ / \ .86\ (\text{efficiency}) * .80 (\text{load factor}) = 7\ \text{kW}$$

$$kWh_{\text{CW pump and CT fan}} = 7\ \text{kW} * 8760\ \text{hours} = 61{,}320\ \text{kWh}$$

$$kW_{\text{saving,NET}} = 107 - 7.0 = 100\ \text{kW}$$

$$kWh_{\text{savings,NET}} = 205{,}110 - 61{,}320 = 141{,}990\ \text{kWh}$$

3.3 Simplified M&V for Cooling Equipment

The simplified M&V procedure for electric-to-electric cooling equipment replacement involves collecting one year of post-consumption kWh data. To determine demand savings, the maximum equipment demand that occurs during the utility peak summer hours must be measured. This can be accomplished with continuous demand metering or spot metering during peak conditions.

3.3.1 Pre-Installation M&V Activities

3.3.1.1 Pre-installation Site Survey

The goals of the pre-installation site survey are to identify the existing equipment, evaluate its schedule of use, and establish the baseline efficiency or coefficient of performance (COP). The Project Sponsor will conduct a survey of all the existing cooling equipment for buildings with a central plant, regardless of whether they will be retrofitted. The information collected should include: equipment type, year, make/model, rated capacity, rated efficiency, operating schedule, and operating sequence. The information will be needed to complete the program application process.

The baseline efficiency is determined by comparing the rated efficiency of the existing unit to the minimum efficiency listed in the Standard Cooling Equipment Table, which are based on ASHRAE 90.1-1999, provided in Appendix A. The baseline efficiency is equal to the more efficient of the two values.

3.3.1.2 Pre-installation Inspection

EPE or its contractor will conduct a pre-installation inspection to verify that the Project Sponsor has properly documented the baseline in the FA. The M&V administrator will make any necessary corrections to the pre-installation survey based on the results of the inspection. **Demolition or removal of existing equipment and/or installation of new equipment cannot commence until the pre-installation inspection is completed and EPE has issued the Project Authorization**

3.3.1.3 Pre-installation Performance Monitoring

The simplified M&V procedure for electric-to-electric cooling equipment replacements does not require pre-installation monitoring of existing equipment. The existing equipment efficiency is determined from the Standard Cooling Equipment Tables, Appendix A. The existing equipment load and operating schedule are assumed to be the same as those of the post-retrofit equipment.

The simplified M&V procedure for electric-to-gas cooling equipment replacement does require pre-installation monitoring of the existing equipment. The maximum demand (measured for a one-hour period) that coincides with the utility peak demand period must be determined, through spot measurements or continuous metering.

3.3.2 Post-Installation M&V Activities

3.3.2.1 Post-installation Equipment Survey

Once the new equipment retrofit is complete, the Project Sponsor conducts and submits a post-installation equipment survey as part of the Installation Report (IR). The survey should include: installed equipment type, year, make/model, rated capacity, rated efficiency, operating schedule, and operating sequence. The cooling equipment description, its location, as well as mechanical design drawings should be included with the IR submittal.

The Project Sponsor must submit manufacturer's documentation of the rated efficiency of all newly installed cooling equipment, based upon ARI test conditions. This documentation will be in the form of manufacturer cut sheets or factory performance test results that document the part load performance of the equipment.

3.3.2.2 Post-installation Inspection

EPE or its contractor will conduct a post-installation inspection to verify that the retrofit was installed as reported and is documented accurately.

3.3.2.3 Post-installation Performance Monitoring

Two basic steps comprise the necessary post-retrofit M&V monitoring activities for electric-to-electric cooling equipment replacements:

1. Measure the maximum demand (measured for a one hour period) that occurs between the hours of 1 PM and 7 PM on weekdays during the months of May through September. This can be accomplished with continuous demand metering (at 15-minute intervals) or a spot measurement during peak conditions.

2. Collect twelve months of post-installation consumption (kWh) data.

For electric-to-gas fuel switching cooling equipment replacements, there are no post-installation metering requirements in the simple M&V procedure.

3.3.3 Calculation of Demand and Energy Savings

3.3.3.1 Electric to Electric Equipment Replacements

Incentive payments based on demand and energy savings are made for electric-to-electric cooling equipment replacement measures. However, demand savings are allowed only for new equipment that will be in operation on weekdays between the hours of 1 PM and 7 PM Monday through Friday for the months of May through September. Peak demand and energy savings are calculated according to Equation 3.3 and Equation 3.4, respectively.

Equation 3.3: Peak Demand Savings

$$\Delta kW = kW_{meter} \cdot \left\{ \left[\frac{COP_{new}}{COP_{base}} \right] - 1 \right\}$$

Where:

kW_{meter}	=	Maximum 15-minute cooling equipment demand measured during the utility peak demand period.
COP_{new}	=	Newly-installed cooling equipment coefficient-of-performance (COP) at ARI design conditions.
COP_{base}	=	Baseline efficiency for retrofitted cooling equipment from Appendix A.

Equation 3.4: Energy Savings

$$\Delta kWh = kWh_{meter} \cdot \left\{ \left[\frac{COP_{new}}{COP_{base}} \right] - 1 \right\} * \left(\frac{CDD(65)_{TMY}}{CDD(65)_{meter}} \right)$$

Where:

kWh_{meter}	=	Summed metered kWh cooling equipment energy use determined for one year.
COP_{new}	=	Newly-installed cooling equipment coefficient-of-performance (COP) at ARI design conditions.
COP_{base}	=	Baseline efficiency for retrofitted cooling equipment from Appendix A.
$CDD(65)_{TMY}$	=	Cooling degree days (base 65 F) for a typical meteorological year (TMY) for the National Climatic Data Center (NCDC) station nearest the site. The value is available in Appendix A, Table A.9.
$CDD(65)_{meter}$	=	Cooling degree days (base 65 F) determined for the metering period for the National Climatic Data Center (NCDC) station nearest the site. The value is determined by EPE based on the metering period start and stop dates using monthly CDD (65) data available from the NCDC at http://lwf.ncdc.noaa.gov/oa/ncdc.html.

Example

In an El Paso office building, a 600-ton, water-cooled, electric centrifugal chiller is replaced with a new chiller of the same type and capacity. The new chiller has an ARI rated COP of 7.6 (0.463 kW/ton). After one year of metering the new chiller energy use totals 697,374 kWh. The maximum demand recorded for the chiller during the metering period that coincided with the utility peak demand period was 286 kW.

This measure is a one-for-one electric chiller replacement. The chiller's performance exceeds the minimum COP (has a higher efficiency) required by the program. One year of continuous, energy-consumption data has been collected. Thus, this measure qualifies for the simple M&V analysis procedure. To complete the savings calculation for the simple M&V, the following additional information is required:

- ASHRAE 90.1-1999 minimum chiller efficiency
- The NCDC station nearest the site
- The NCDC station TMY CDD(65) – Provided in the Appendices.
- The NCDC station CDD(65) determined for the metering period

From Standard Cooling Equipment Tables, the minimum COP for a water-cooled centrifugal chiller of 300 tons or more is **6.1** (or 0.577 kW/ton; see the Standard Cooling Equipment Tables). The NCDC weather station is the El Paso station. The cooling degree day data for the station are **2094 (°F day) for TMY2** and **2078(°F day)** for the metering year.

Based on the collected data and system characteristics, the demand savings are determined to be:

$$\Delta kW = kW_{meter} * \left\{ \left[\frac{COP_{new}}{COP_{base}} \right] - 1 \right\}$$

$$\Delta \mathrm{kW} = 286 * \left\{ \left[\frac{7.6}{6.1} \right] - 1 \right\}$$

Thus, the estimated demand savings are **70.4 kW**.

Based on the collected data and system characteristics, the energy savings are determined to be:

$$\Delta kWh_{chiller} = kWh_{meter} * \left\{ \left[\frac{COP_{new}}{COP_{base}} \right]_{rated} - 1 \right\} * \left(\frac{CDD(65)_{TMY}}{CDD(65)_{meter}} \right)$$

$$\Delta \mathrm{kWh} = 697{,}374 * \left\{ \left[\frac{7.6}{6.1} \right] - 1 \right\} * \left(\frac{2094}{2078} \right)$$

Thus, the energy savings are **172,926 kWh**.

3.3.3.2 Electric to Gas Equipment Replacements (Fuel switching)

Incentive payments based on demand and energy savings are made for electric-to-gas fuel switching projects involving the replacement of cooling equipment. Demand savings are allowed only for equipment that operates on weekdays between the hours of 1 P.M. and 7 P.M. Monday through Friday for the months of May through September. Peak demand savings are calculated according to Equation 3.5.

Equation 3.5: Peak Demand Savings for Fuel Switching Measures

$$\Delta kW = kW_{meter}$$

Where:

kW_{meter}	=	Maximum existing, electric, cooling equipment demand measured during the utility peak demand period

Energy savings are calculated by subtracting the new fuel consumption (converted to kWh using a heat rate of 10,500 Btu/kWh) from the pre-installation energy consumption. Energy savings are calculated according to Equation 3.6.

Equation 3.6: Energy Savings for Fuel Switching Measures

$$\Delta \text{kWh} = \text{kWh}_{\text{meter}} - \text{Btu}_{\text{gas}} \times \left(\frac{1}{10{,}500\ (\text{Btu/kWh})} \right)$$

Where:

kWh_{meter}	=	Existing, electric, cooling equipment annual energy consumption measured or predicted
Btu_{gas}	=	Measured annual post-retrofit gas consumption

4

Simplified M&V Guidelines for Constant Load Motor Measures

4.1 Overview

This measurement and verification (M&V) method is appropriate for projects involving existing motors serving a constant load being replaced with higher efficiency motors of equal or lesser capacity (horsepower). The rated efficiency of the new motor must exceed the minimum efficiency standard defined in the Table of Standard Motor Efficiencies in Appendix B to be eligible for the program. Potential retrofit equipment includes:

- Constant load chilled water, hot water, or condenser water pumps
- Constant speed exhaust, return, and supply fans without dampers or pressure controls
- Single-speed cooling tower fans
- Constant load industrial processes
- Similar capacity, constant speed, energy efficiency motors
- Smaller, constant speed, energy efficiency motors when the existing motor is oversized

These M&V procedures are not appropriate for motor change outs that are accompanied by:

- Changes in operating schedule
- Changes in operating hours
- Changes in flow rate
- Changes in motor controls (except VSDs)

If the proposed retrofit does not meet the constant load requirements, or involves scheduling or operational changes, refer to the *Full M&V Guidelines for Generic Variable Loads* in Chapter 7 for appropriate M&V techniques.

In the COMMERCIAL Standard Offer Program, the calculation of demand and energy savings for motor replacements is based on the baseline and post-installation kW, the difference in efficiency of the baseline and new motors, and the motor operating hours. The operating hours are assumed the same for existing and new motors. The baseline motor efficiency is based on the minimum efficiency rating defined by the Table for Standard Motor Efficiencies in Appendix B. The Table of Standard Motor Efficiencies is categorized by motor size and rotation speed. No incentive payments are made for replacement motors with efficiencies equal to or less than the baseline efficiency. In addition to having a higher efficiency than baseline motors, all new motors should meet minimum equipment standards as defined by state and federal law.

The recommended M&V approach for motors includes some or all of the following data collection activities:

- Compiling inventories for existing and new motors
- Short-term metering of existing motors to verify constant loading (if warranted)
- Spot metering of all existing and new motors
- Short-term metering of a sample of the new motors to determine operating hours

4.2 Determination of Baseline Operating Characteristics

The M&V steps that characterize the existing motors are:

1. Pre-installation equipment survey (to be conducted by the Project Sponsor)
2. Spot measurement of demand (kW), and short-term metering of existing motors, where needed (to be conducted by the Project Sponsor)
3. Pre-installation inspection (to be conducted by EPE or its contractor)

4.2.1 Pre-installation Equipment Survey

The Project Sponsor should conduct a pre-installation survey to inventory the equipment to be replaced. Motor location and corresponding facility mechanical plans should be included with the survey submittal as part of the Final Application. At a minimum, the surveys should include the following for each existing motor:

- Motor name
- Load served
- Motor location
- Operating schedule
- Equipment manufacturer
- Nameplate data including model, horsepower, and speed

The baseline motor efficiency should be determined from the Table of Standard Motor Efficiencies based on the existing motor data provided in the Final Application.

Any M&V activities that need to be conducted prior to the demolition of existing equipment (i.e., short-term measurements) should take place at this time. **Demolition of existing equipment and/or installation of new equipment cannot begin until baseline M&V activities are completed, the pre-installation inspection is completed, and EPE has approved the Final Application and issued a Project Authorization.**

4.2.2 Spot and Short-term Measurement of Existing Motors

To establish the baseline kW, the Project Sponsor must conduct spot measurements of the power draw of the existing motors. If the constant load criterion cannot be verified by visual inspection, then short-term metering of the power draw or current (amperes) of the existing motors may also be required.

The verification of constant motor loading by short-term metering is warranted in situations where the effect of piping, valves, controls, or processes on motor load is uncertain. A motor load is considered to be constant if **90%** of all non-zero observations are within **±10%** of the running average kW. If short-term metering demonstrates that the proposed retrofit does not meet the constant load definition, then the Project Sponsor should refer to the *Full M&V Guidelines for Generic Variable Loads* in Chapter 7 for appropriate M&V techniques.

To compensate for the variations in spot measurements that occur even in constant-load motors, the Project Sponsor may need to develop normalization factors for groups of like motors serving similar loads. A normalization factor is the ratio of a motor's average current (from short-term metering) to its spot measured current. EPE may require the use of a normalization factor for projects with a group or groups of identical motors.

The minimum efficiency standard for the existing motor type is listed in the Table of Standard Motor Efficiencies. If the efficiency of the existing motor is greater than or equal to the minimum efficiency standard, then the baseline demand is equal to the spot measured value. If not, then the baseline demand is calculated according to Equation 4.1.

Equation 4.1:

$$\text{Baseline Demand [kW]} = \frac{\text{Existing Motor Efficiency}}{\text{Standard Minimum Efficiency}} * \text{Spot Measured Existing Motor Demand [kW]}$$

4.2.3 Pre-installation Inspection

EPE will conduct a pre-installation inspection to verify that the existing condition is as reported in the pre-installation equipment survey in the Final Application. EPE will require the Project Sponsor to make any necessary corrections to the Final Application based upon the results of the inspection.

Demolition of existing equipment and/or installation of new equipment cannot begin until the pre-installation inspection is completed and EPE has approved the Final Application and issued a Project Authorization.

4.3 Document Post-Retrofit Operating Characteristics

The M&V steps that characterize the new motors are:

1. Post-installation equipment survey (to be conducted by the Project Sponsor)
2. Spot measurements of the power draw (one-hour average values) of all the new motors (to be conducted by the Project Sponsor)
3. Post-installation inspection (to be conducted by EPE or its contractor)
4. Short-term metering of operating hours for a sample of existing motors (to be conducted by the Project Sponsor)

4.3.1 Post-installation Equipment Survey

The Project Sponsor shall conduct a post-installation equipment survey, similar to the pre-installation equipment survey described above. The survey shall reflect the actual, as-built conditions of the project. The post-installation survey will be included in the Installation Report.

4.3.2 Spot Measurements of Motor Demand

The Project Sponsor must conduct spot measurements of the power draw (one-hour average values) of each new, high-efficiency motor in order to establish the post-installation demand. The Project Sponsor will report the measured kW as part of the Installation Report.

4.3.3 Post-installation Inspection

Once EPE receives the Installation Report for the motor project, EPE or its contractor will conduct a post-installation inspection to verify that the equipment specifications are correctly reported in the Installation Report. EPE will require the Project Sponsor to make any necessary corrections to the Installation Report based upon the results of the inspection.

4.3.4 Short-term Metering of Motor Operating Hours

Baseline motor operating hours are assumed to be the same as post-installation operating hours, and should be determined after new motor installation. Short-term metering is used to determine both pre- and post-installation operating hours.

After EPE approves the Installation Report, the Project Sponsor should begin short-term metering of motor operating hours. The metering must be conducted for a minimum period of one week, or a sufficient amount of time to capture the full range of operation. The motor annual operating hours are calculated from the metering data according to Equation 4.2.

Equation 4.2:

$$\text{Annual Operating Hours [hrs/yr]} = \frac{\text{Motor On-time during Metering Period [hrs]}}{\text{Length of Metering Period [hrs]}} * 8{,}760\ \text{[hrs/yr]}$$

For projects in which a large number of equal-sized motors with the same application and operating schedule will be replaced, metering may be conducted on a sample of the motors and the results extrapolated to the applicable population. If this approach is adopted, EPE will assist the Project Sponsor in selecting the motors to be metered.

The Project Sponsor should include electronic copies of the unprocessed data files as part of the Savings Report.

4.4 Calculation of Peak Demand and Energy Savings

Demand savings are calculated for equipment that operates during the summer peak period, which is defined as weekdays between the hours of 1 p.m. and 7 p.m. from May 1 through September 30. The peak demand savings and energy savings are calculated according to Equation 4.3 and Equation 4.4, respectively.

Equation 4.3:

$$\text{Peak Demand Savings [kW]} = \text{Baseline Demand [kW]} - \text{Spot Measured New Motor Demand [kW]}$$

Equation 4.4:

Energy Savings [kWh] = Peak demand savings [kW] * Annual Operating Hours [hrs]

The Project Sponsor reports the peak demand and energy savings to EPE in the project Savings Report.

Example

A constant-speed process motor at an agricultural processing plant will be replaced with a smaller, high-efficiency motor. As indicated on its nameplate, the existing motor is a 200 hp, 1800 RPM enclosed motor with a nominal efficiency of 0.91. This motor will be down-sized to a 150 hp motor with a nominal efficiency of 0.96.

As the first step in the M&V, a spot measurement of the existing motor was made and indicated a power draw of 165.3 kW.

The minimum efficiency standard for the existing motor is 0.95 (as given in the Minimum Standard Motor Table) which is greater than the efficiency of the existing motor; therefore, the baseline demand is calculated according to Equation 4.1.

(a) Baseline motor demand = 165.3*(0.91/0.95) **= 158.3 kW**

Following installation of the new motor, a spot measurement was made, and indicated an average, one hour, power draw of 117.9 kW.

Post-installation metering of operating hours was then conducted for a one-week period. The metering results show that the motor was operating for 81 hours out of the 168 hours in the metering period. The annual operating hours were calculated using Equation 4.2, as shown below.

(b) Annual operating hours = (81/168)*8760 **= 4224 hrs**

The peak demand savings and energy savings were then calculated using Equations 4.3 and 4.4, respectively, as shown below.

(c) Peak demand savings = 158.3 - 117.9 **= 40.4 kW**

(d) Annual energy savings = 40.4 * 4224 **= 170,650 kWh**

4.5 Variable Speed Drives on Constant Baseline Motors

Installing variable-speed drive (VSD) controllers on motors that serve a constant baseline load requires a modified motor M&V procedure. In order to qualify for the EPE 2008 COMMERCIAL Standard Offer Program, VSDs must be installed in conjunction with other energy efficiency measures that deliver demand as well as energy savings. Potential retrofit projects that might include VSDs include:

- Converting constant air volume (CAV) systems to variable air volume (VAV)
- Retrofitting central chiller plants
- Replacing standard efficiency electric motors with high efficiency models

Motors that are scheduled for the installation of VSDs follow the same **Determination of Baseline Operating Characteristics** described earlier in this chapter. If the efficiency of the existing motor is greater than or equal to the minimum listed in the Table of Standard Motor Efficiencies, then the baseline demand is equal to the spot measured value; if not, then it is calculated according to Equation 4.1.

After the VSD and associated project retrofit has been installed, the Project Sponsor will again **Document Post-Retrofit Operating Characteristics**. The **Post-installation equipment survey** and the **Post-installation inspection** procedures are the same as described earlier in this chapter.

After EPE has conducted a post-installation inspection and approved the project Installation Report, the Project Sponsor should begin short-term metering[6] of the power draw (kW) of the motors. The data must be recorded at intervals of 15 minutes or less. However, averaged one-hour values are used in the calculation of demand and energy savings. For calculating peak demand, the metering must occur during the summer peak period.

The duration of the metering period must be sufficient to capture the full range of motor operation. If the motor load varies only on a daily basis and not seasonally, then a metering period of one week is generally sufficient. If the motor load or operating hours vary with weather or other seasonal parameters (e.g., production schedules, school calendars), then at least two weeks of metering during each operating period is generally necessary. For example, if the motor serves cooling equipment, then the metering should occur for at least two weeks during the winter months and two weeks during the summer months.

The metering data are used to determine three values:

> **Peak summer period demand (kW):** Equal to the maximum-recorded peak summer period demand (one hour average values, where the summer peak period is defined as weekdays, between the hours of 1 PM and 7 PM, from May 1 through September 30).
>
> **Average demand (kW):** Equal to the average recorded demand. For motors with seasonal load patterns, the average demand should be weighted according to the relative length of each seasonal period (see VSD example).
>
> **Annual operating hours:** Calculated from the metering data according to Equation 4.5. For motors with seasonal load patterns, the annual operating hours should be weighted according to the relative length of each seasonal period.

Equation 4.5:

$$\text{VSD Annual Operating Hours [hrs/yr]} = \frac{\text{Motor On-time during Metering Period [hrs]}}{\text{Length of Metering Period [hrs]}} * 8{,}760 \text{ [hrs/yr]}$$

For projects in which a large number of equal-sized motors with the same application and operating schedule will be replaced, M&V may be conducted on a sample of the motors and

[6] Long-term monitoring may be required for motors with non-uniform or unpredictable load patterns.

the results extrapolated to the applicable population. If this approach is adopted, the utility Program Manager will select the motors to be metered.

The peak demand savings and energy savings are calculated according to Equation 4.6 and Equation 4.7, respectively.

Equation 4.6:

$$\text{VSD Peak Demand Savings [kW]} = \text{Baseline Demand [kW]} - \text{Peak Summer Period Demand [kW]}$$

Equation 4.7:

$$\text{VSD Energy Savings [kWh]} = (\text{Baseline Demand [kW]} - \text{Average Demand [kW]}) * \text{Annual Operating Hours [hrs]}$$

VSD Example

The constant air volume ventilation system at a commercial office building will be converted to a variable air volume (VAV) system. The conversion involves retrofitting four 50 hp supply fan motors with variable speed drives (VSDs). Additionally, the existing motors will be replaced with premium efficiency motors. The M&V procedures for a single motor are illustrated below. In general, the same procedure would be followed for all four motors.

A spot measurement of the power draw of the existing motor was made and gave a reading of 42.3 kW. The nameplate on the existing motor indicates that it is an 1800 RPM, enclosed motor with a nominal efficiency of 0.92. From Appendix B, the minimum efficiency standard for this type of motor is 0.93; therefore, the baseline demand is calculated according to Equation (a)

(a) Baseline demand = (0.92/0.93)*42.3 = 41.8 kW

Because the motor load is weather dependent, short-term post-installation metering must be conducted during both summer and winter months. Thus, after the new motor and VSD are installed, short-term metering of the motor's power draw (kW) is conducted for two weeks in January (winter) and two weeks in July (summer).

The metering data indicates that the <u>peak</u> (one hour) summer period demand was 37.6 kW. The <u>average</u> demand during the January metering period was 5.3 kW, and the <u>average</u> demand during the July metering period was 19.8 kW. The summer and winter periods are assumed to account for equal portions of the year; therefore, the metering results are weighted evenly for the two periods. Thus, the average demand is 12.6 kW.

The metering data indicates that motor was operating for 88 hours during the 336-hour January metering period, and for 110 hours during the 336-hour July metering period. As discussed above, the results from the two metering periods are weighted evenly; thus, the annual operating hours are calculated as shown in Equation (b).

(b) Annual operating hours = [(88/336+110/336)/2]*8760 = 2581 hours

The peak demand savings and energy savings for this motor are calculated according Equations (c) and (d), respectively.

(c) Peak demand savings = 41.8-37.6 = 4.2 kW

(d) Energy savings = (41.8-12.6)*2581 = 73,365 kWh

5 Simplified M&V Guidelines for Application of Window Films

5.1 Overview

The installation of window films decreases the window-shading coefficient and reduces the solar heat transmitted to the building space. During months when perimeter cooling is required in the building, this measure decreases cooling energy use.

The simplified M&V guidelines developed for this measure are applicable for window films applied to south- and west-facing windows only. The measure demand and energy savings are calculated based on the window-film area, change in shading coefficient, and cooling equipment efficiency. Savings for window film measures are determined using the *Deemed Savings Helper* calculation spreadsheet available from the EPE COMMERCIAL Web site.

The following steps comprise the simplified M&V procedure for window-film installations.

1. Collect data characterizing the existing south and west windows including: shading coefficient, type of interior shading devices, and presence of exterior shading from buildings or other obstacles. Identify the type and rated efficiency of the cooling equipment in the building.
2. Document the installed window-film shading coefficient and window application area for the south and west windows.
3. Based on the characteristics of the existing windows, newly installed window-films, and cooling equipment; determine the annual demand and energy savings using the window-film calculation spreadsheet.

5.2 Pre-installation M&V Activities

5.2.1 Pre-installation Site Survey

The goal of the pre-installation site survey is to identify the existing south and west window characteristics. At a minimum, the surveys should include the following data for the south and west windows:

- Existing window description
- Existing window shading coefficient
- Window area by cardinal orientation
- Description of interior shading devices
- If applicable, an estimate of combined window-interior shading coefficient determined from 1997 ASHRAE Fundamentals, Chapter 29, Tables 24-29
- Description of exterior shading
- Description of building cooling equipment

This information will be included as part of the Initial Application (IA). For window film measures, the IA should be submitted after the project site has been identified. Submitting the IA prior to site identification could result in significant under or over estimation of savings since variations in window area and shading characteristics between sites are large.

5.2.2 Pre-installation Inspection

After the FA is submitted, EPE or its contractor will conduct a pre-installation inspection to verify that the Project Sponsor has properly documented the baseline characteristics of the building, including: window area by orientation, shading devices, and cooling equipment type. The M&V administrator will inform the Project Sponsor of any necessary corrections to be made to the pre-installation survey based on the results of the inspection. Removal or demolition of existing shading devices and equipment or installation of new films, shading devices, and equipment cannot commence until the pre-installation inspection is completed.

5.3 Post-Installation M&V Activities

5.3.1 Post-installation Survey

The Project Sponsor should provide manufacturer's data for the window films; specifically the National Fenestration Rating Council (NFRC) shading coefficient for the installed window films. The area of the window films applied for each different solar orientation must also be specified. This data is reported using the available window film inventory form (on the downloads page of the EPE COMMERCIAL Web site) or via an online reporting form.

5.3.2 Post-installation Inspection

EPE or its contractor will conduct a post-installation inspection to verify the documented characteristics of the building, windows, shading, cooling equipment, and window films. The M&V administrator will inform the Project Sponsor of any necessary corrections to be made to the pre-installation survey based on the results of the inspection. If the project is comprised of many small installations, EPE will inspect a randomly selected sample of the window-film installations completed by the Project Sponsor.

5.4 Calculation of Energy Savings

The window film demand and energy savings result from a reduction in demand and energy use of cooling equipment. For evaluating savings, a calculation worksheet is available as part of the online program applications on the EPE COMMERCIAL SOP Web site. The savings estimates rely on tabulated values of solar heat gain factors (SHGF) as published in the 1997 ASHRAE Fundamentals, Chapter 29, Table 17. The ASHRAE data represent the amount of solar radiation that is transmitted through single-pane clear glass for a cloudless day at 32^{o} N Latitude for the 21st day of each month by hour of day and solar orientation. The solar gain values are translated to electric energy savings by considering the cooling equipment efficiency. In the calculation, the cooling equipment efficiency equals the rated efficiency of the installed equipment or the ASHRAE Standard 90.1-1999 minimum cooling equipment efficiency (see the Standard Cooling Equipment Tables – Appendix A), whichever is more efficient.

To determine the coincident, peak summer demand savings associated with window films, the highest, hourly, ASHRAE SHGF value that occurs during the summer peak period is identified for each of the south and west building orientations. The available data nearest the EPE service territory are presented in Table 5.1. The building demand savings are determined from the maximum of these peak SHG values for the applicable window orientations.

To determine cooling energy savings associated with window films, the ASHRAE SHGF data are aggregated into daily totals for weekdays during the months of April through October. These totaled, SHG values are presented in Table 5.1. In the table, orientations that are symmetrical relative to the southern sky have the same SHGF values.

Table 5.1: Solar Heat Gain Determined for 32°N Latitude

Orientation	Solar heat gain (Btu/ft^2-year)	Peak hour solar heat gain (Btu/hr-ft^2-year)
SE	158,323	59
SSE	133,894	119
S	120,095	164
SSW	133,894	189
SW	158,323	219
WSW	168,978	228
W	162,388	220
WNW	139,995	208
NW	106,876	176

The data from Table 5.1 are used to determine the demand and energy savings associated with the window film measure using the equations below. Equation 5.1 presents the demand savings calculation. Demand savings are determined for the window orientation that results in the highest savings. Demand savings by orientation are not additive.

Equation 5.1: Calculation of peak demand savings for window films		
$$kW_{savings,o} = \frac{A_{film,o} \cdot SHGF_o \cdot \left(SC_{pre,o} - SC_{post,o}\right)}{3413 \cdot COP}$$		
$$kW_{savings,peak} = kW_{savings,o,\max}$$		
Where:		
$kW_{savings,o}$	=	Peak demand savings per window orientation.
$kW_{savings,peak}$	=	Peak summer demand savings.
$A_{film,o}$	=	Area of window film applied to orientation (ft^2).
$SHGF_o$	=	Peak solar heat gain factor (Btu/hr-ft^2-yr) for orientation of interest from Table 5.1 on vertical glazing at 32°N latitude.
SC_{pre}	=	Shading coefficient for existing glass/interior-shading device.
SC_{post}	=	Shading coefficient for new film/interior-shading device.
COP	=	Cooling equipment COP or SEER based on ASHRAE Standard 90.1-1999 or actual COP of equipment, whichever is greater.
3413	=	Conversion factor (Btu/kW).

Equation 5.2 presents the annual energy savings calculation for window films. The total annual energy savings is equal to the sum of the savings determined for each orientation, as shown below.

Equation 5.2: Calculation of annual cooling energy savings		
$$kWh_{savings,o} = \frac{A_{film,o} \cdot SHGF_o \cdot \left(SC_{pre,o} - SC_{post,o}\right)}{3413 \cdot COP}$$		
$$kWh_{savings} = \sum kWh_{savings,o}$$		
Where:		
$kWh_{savings,o}$	=	Annual energy savings per window orientation.
SHG_o	=	Solar heat gain factor (Btu/yr) for orientation of interest from Table 5.1.

The following is an example of the savings calculations for a window film project.

Example

Window films are installed on an office building. The building does not have interior shading devices. The building is not self-shaded or shaded externally by neighboring buildings. The window shading characteristics, film surface area, and SHGFs are presented below. The SHG and SHGF values are based on the data presented in Table 5.2. Cooling is provided to the building by a 600 ton, water-cooled, centrifugal chiller. The ASHRAE 90.1-1999 rated COP for this type of chiller is 6.1, as specified in the EPE Standard Cooling Equipment Tables.

Orientation	South	West
Area (ft^2)	10,000	10,000
Window SC (baseline)	0.95	0.95
Window SC (w/films)	0.35	0.35
Interior Shading	None	None
SHG (Btu/ft^2-yr)	120,095	162,388
Peak SHGF ($Btu/hr\text{-}ft^2$-yr)	164	220

The energy savings for installing the window films can be found using the information provided and Equations 1a and 1b. Due to the absence of interior shading devices in the building, the window shading coefficients are used in the savings calculation. The energy savings for the south and west films are equal to:

$$kWh_{savings,s/w} = \frac{10{,}000 \cdot 120{,}095 \cdot (0.95 - 0.35)}{3{,}413 \cdot 6.1} + \frac{10{,}000 \cdot 162{,}388 \cdot (0.95 - 0.35)}{3{,}413 \cdot 6.1}$$

$$kWh_{savings,s/w} = 34{,}611 + 46{,}799 = 81{,}410$$

The demand savings for installing the window films can be found using the information provided and Equation 5.1. Due to the absence of interior shading devices in the building, the window shading coefficients are used in the savings calculation. The demand savings for the south and west films are equal to:

$$kW_{savings,s} = \frac{10{,}000 \cdot 164 \cdot (0.95 - 0.35)}{3{,}413 \cdot 6.1} = 47.3$$

$$kW_{savings,w} = \frac{10{,}000 \cdot 220 \cdot (0.95 - 0.35)}{3{,}413 \cdot 6.1} = 63.4$$

$$\therefore \quad kW_{savings,peak} = kW_{savings,w} = 63.4\ kW$$

6 Measurement and Verification Using Stipulated Savings Factors

6.1 Overview

Stipulated savings factor measurement and verification (M&V) techniques involve establishing the efficiency of a system before and after a retrofit by multiplying the difference by an agreed-upon or "stipulated" factor, such as operating hours or system load. These stipulated factors represent a project's potential to generate savings based on engineering analysis and simple verification activities.

Stipulated savings factor M&V methods are appropriate only for projects in which the following apply for the baseline and post-installation case:

- Electrical demand is constant, or varies as a function of operating scenarios, e.g., damper position for baseline or motor speed for post-installation; the electrical demand for each operating scenario can be defined with spot measurements.
- Operating hours as a function of operating scenario can be stipulated.

If the equipment involved in a project has a complex load profile and/or a complicated operating schedule, a different M&V method should be used.

Any Project Sponsor considering the use of stipulated savings factors not specified in this program should consult with EPE prior to submitting an M&V plan.

The M&V method described here is based on Option A of the International Performance Measurement and Verification Protocol (IPMVP). Valuable insights on this method can be found in the IPMVP.

6.2 Data Types

Three general types of data may be needed to estimate energy savings with an M&V plan using stipulated savings factors:

- Stipulated values based on: manufacturer's data, historical values, documented schedules from Energy Management Systems, operator's logs, results from measures in similar facilities.
- Observations or inspections used to verify equipment type, nameplate data, counts, applications, and general operating characteristics.
- Spot/short term metering may be used to determine power draw for different operating characteristics.

The types of data needed to verify energy savings for a specific project will depend on its complexity and the type of relevant stipulated data available. **All stipulated factors must be clearly explained and supported by the Project Sponsor in the M&V plan.** Note that there may be sizable differences between published equipment performance information and actual operating data. Where discrepancies exist or are believed to exist, equipment performance parameters should be measured directly.

6.3 Documenting Baseline Operating Characteristics

To establish the baseline operating characteristics of the existing equipment, the following steps are taken:

1. The Project Sponsor conducts a pre-installation equipment survey.
2. EPE and/or its contractor conducts a pre-installation inspection.
3. The Project Sponsor develops and verifies stipulated savings factors.

6.3.1 Pre-installation Equipment Survey

The Project Sponsor is required to conduct a pre-installation equipment survey to be submitted as part of the Final Application. The purpose of the survey is to inventory all existing equipment to be affected by the project, and to propose equipment to be installed. For each piece of existing equipment, the survey should list (as applicable): location, manufacturer, model number, rated capacity, energy use factors (such as voltage, rated amperage, fixture wattage), nominal efficiency, the load served, and any other identifiers that affect system energy consumption.

6.3.2 Pre-installation Inspection

EPE or its contractor will conduct a pre-installation inspection to verify that the Project Sponsor has properly documented the baseline equipment in the survey, and that the stipulated savings values in the M&V plan are appropriate. If significant errors are found, EPE will inform the Project Sponsor that the submitted survey (which is a part of the Final Application) must be corrected and resubmitted.

6.3.3 Development and Verification of Stipulated Savings Factors

The Project Sponsor may use a variety of sources in the development of stipulated savings factors, including manufacturer's data, historical values, documented schedules from energy management systems, operator's logs, and results from measures in similar facilities. The pre-installation equipment inspection will be used to confirm that the stipulated factors proposed in the M&V plan are appropriate for the equipment type, application, and general operating characteristics of the project. Spot- or short-term monitoring may be required to confirm the applicability of a stipulated savings factor to a specific project.

EPE must approve all stipulated savings factors, so all data sources, methodologies, and assumptions used in their development by the Project Sponsor must be clearly outlined in the M&V plan.

6.4 Compliance with Energy Standards

When using stipulated savings methods, the M&V plan should document how baseline consumption values will be adjusted to comply with minimum state and federal energy standards with respect to the following:

- Baseline equipment should meet prescriptive efficiency standards requirements for affected equipment (e.g., ASHRAE Standard 90.1-1999).
- The baseline does not have to comply with performance compliance methods that require the project site to meet an energy budget.
- Demand and energy savings should be calculated with the incorporation of minimum state and federal energy efficiency standards or codes into the determination of baseline energy use.

6.5 Documenting Post-Installation Operating Characteristics

To establish the post-installation operating characteristics of the newly installed equipment, the following steps should be taken:

1. The Project Sponsor conducts a post-installation equipment survey.
2. EPE or its contractor conducts a post-installation inspection.
3. The Project Sponsor verifies stipulated savings factors using data from the installed system.

6.5.1 Post-installation Equipment Survey

The Project Sponsor is required to conduct a post-installation equipment survey to be submitted as part of the Installation Report. The purpose of this equipment survey is to document the equipment that was actually installed as part of a project. For each piece of equipment, the survey should list (as applicable): location, manufacturer, model number, rated capacity, energy use factors (such as voltage, rated amperage, fixture wattage), nominal efficiency, the load served, and any independent variables that affect system energy consumption.

6.5.2 Post-installation Inspection

EPE or its contractor will conduct a post-installation inspection to verify that the Project Sponsor has properly documented the installed equipment and that the stipulated savings values in the M&V plan are appropriate. After the inspection, EPE will either accept or reject the Installation Report and the proposed stipulated savings factors based on the inspection results and project review.

6.5.3 Verification of Stipulated Savings Factors

The post-installation inspection results will be used to verify that the stipulated factors proposed in the M&V plan are still appropriate for the installed equipment and its general operating characteristics. Spot- or short-term post-installation monitoring may be required to confirm their applicability to a specific project.

6.5.4 Calculation of Demand and Energy Savings

Once the installed equipment has been verified to be operating properly and the proposed stipulated savings factors have been approved by EPE, the Project Sponsor must calculate the demand and energy savings generated by the project. The best approach for calculating the project's savings will vary depending on the type of project and the data collected, but, in general, actual metered/measured equipment operating data should be used as much as possible.

All equations to be used in calculating energy savings should be included in the project's M&V plan. For example, for a project that decreases equipment electric demand but causes no change in operating hours, the stipulated savings calculations might appear as follows:

Equation 6.1:

$$\text{Demand Savings [kW]} = kW_{Baseline} - kW_{Post\text{-}installation}$$

Equation 6.2:

$$\text{Annual Energy Savings [kWh]} = (kW_{Baseline} - kW_{Post\text{-}installation}]) * Hours_{Stipulated}$$

Where:

$kW_{Baseline}$ = Baseline equipment demand as measured by pre-installation short-term metering during the utility peak, summer coincident load period.

$kW_{Post\text{-}installation}$ = Post-installation equipment demand as measured by short-term metering during the utility peak, summer coincident load period.

$Hours_{Stipulated}$ = Annual operating hours determined using stipulated factor.

6.6 Project-Specific M&V Issues

When stipulated factors will be used to calculate energy savings, the M&V plan must address the following issues:

- How accurately stipulated factors will reflect actual energy savings
- How well the stipulated factors are supported by other data sources, physical observations, or monitoring data
- How appropriate the stipulated factors are to the equipment and operating conditions involved in the project
- How the baseline energy consumption estimates will incorporate minimum state and federal energy efficiency standards or codes

7 Measurement and Verification for Generic Variable Loads

7.1 Overview

Projects that improve the efficiency of end-uses that exhibit variable energy demand or operating hours may require continuous post-installation metering to measure and verify energy savings. Examples of such projects include:

- Upgrading building automation systems
- Installing new industrial process equipment or systems
- Comprehensive chiller plant modifications, including chillers, cooling towers, pumps, etc.

The use of continuous metering for measurement and verification (M&V) of variable loads normally involves four steps:

1. Surveying the pre-installation system(s). As with all M&V methods, the Project Sponsor must audit existing systems to document relevant components (e.g., piping and ductwork diagrams, control sequences, and operating parameters).

2. Establishing a baseline model (e.g., an equation that determines energy use when key independent variables are known). All, or a representative sample, of the existing systems should be metered to establish regression-based equations or curves for defining baseline system energy use as a function of appropriate variables (e.g., weather or cooling load). Adjustments may be required for the models to comply with minimum energy efficiency standards.

3. Monitoring post-installation energy use and/or independent variables e.g., weather. Monitoring can be done continuously throughout a full year or for representative periods of time during each performance year.

4. Determining the savings by subtracting the post-installation energy use from the baseline energy use (as indicated in the baseline model).

Most energy retrofits can be monitored and savings verified using this method. However, there are retrofits that cannot be quantitatively verified using continuous post-installation metering, such as window tinting.

The M&V method described here is based on Option B of the International Performance Measurement and Verification Protocol (IPMVP). Valuable insights on this method can be found in the IPMVP.

7.2 Documenting Baseline Operating Characteristics

To establish the baseline operating characteristics of the existing systems, the following steps are taken:

1. The Project Sponsor conducts a pre-installation equipment survey.
2. EPE and/or its contractor conducts a pre-installation inspection.
3. The Project Sponsor conducts any necessary M&V activities.
4. The Project Sponsor develops a baseline energy consumption model based on metered system data.

7.2.1 Pre-installation Equipment Survey

The Project Sponsor is required to conduct a pre-installation equipment survey, to be submitted as part of the Final Application. The purpose of the pre-installation equipment survey is to inventory all existing equipment to be affected by a project, and to propose the replacement equipment to be installed. For each piece of equipment, the survey should list (as applicable): location, manufacturer, model number, rated capacity, energy use factors (such as voltage, rated amperage, MBtu/hr, fixture wattage), nominal efficiency, the load served, and any independent variables that affect system energy consumption.

7.2.2 Pre-installation Inspection

EPE or its contractor will conduct a pre-installation inspection to verify that the Project Sponsor has properly documented the baseline equipment. If significant errors are found in the survey, EPE will inform the Project Sponsor that the submitted survey (which is a part of the Final Application) must be corrected and resubmitted.

7.2.3 Pre-installation Data Collection

Before making any efficiency modifications to existing equipment, the Project Sponsor must monitor the following variables simultaneously:

> **Independent variables that affect energy use.** Examples of such data are ambient temperature, control outputs, flow rate, cooling tons, and building occupancy.
>
> **System energy consumption.** Energy demand (e.g., kW) of the equipment to be affected by the project metered over a representative time period sufficient to document the full range of system operation.

Typically, metering observations should be made in 15-minute intervals, unless the Project Sponsor can demonstrate that longer intervals are sufficient and EPE approves such intervals.

If multiple, identical equipment components or systems are to be modified (e.g., multiple heating boilers), the M&V plan may specify metering of only a statistical sampling of the equipment.

In some cases, a dependent variable may serve as an accurate proxy for energy demand and may be monitored in lieu of energy metering. Examples of dependent variables that may be used as a proxy for energy include amperes and rotating equipment speed. If proxy variables are used, the Project Sponsor must show that the proxy variable is representative of the actual demand.

7.2.4 Baseline Model Development

The energy use of most projects will be influenced by independent variables. For such projects, a model must be developed (typically using regression techniques) that links independent-variable data to energy use. The methodologies for creating such a model must be included in the Final Application and approved by EPE.

The results of energy-input metering and variable(s) monitoring will be used to establish the pre-installation relationship between these quantities. This relationship will be known as the "System Baseline Model" and will probably be presented in the form of an equation. Regression analysis is typically used to develop such an equation, although other mathematical methods may be approved. If regression analysis is used, it must be demonstrated that that the model is statistically valid.

The criteria for establishing statistical validity of the model are:

- The model makes intuitive sense; e.g., the explanatory variables are reasonable, and the coefficients have the expected sign (positive or negative) and are within an expected range (magnitude).
- The modeled data represent the population.
- The model's form conforms to standard statistical practice and modeling techniques for the system in question.
- The number of coefficients is appropriate for the number of observations.
- The T-statistic for each term in the regression equation is equal to at least 2 (indicates with 95% confidence that the associated regression coefficient is not zero). The regression R^2 is at least 80%.
- All data entered into the model are thoroughly documented and model limits (range of independent variables for which the model is valid) are specified.

Raw data used in model development must be submitted with the Final Application or Installation Report. EPE or its contractor will make a final determination on the validity of models and monitoring plans and may request additional documentation, analysis, or metering as necessary.

7.3 Compliance with Energy Standards

The baseline model must comply with all applicable federal and state energy standards and codes. If any existing equipment that will be part of the project does not meet the applicable standards, the Project Sponsor must document how the baseline model will be adjusted to account for the standards. It is possible that two baseline models will be developed – an existing system baseline model and a minimum-standard system baseline model. In general, however, the M&V plan should document how baseline values are in compliance, or will be adjusted to comply, with the following:

- Baseline equipment characterization should meet prescriptive efficiency standards requirements for affected equipment (e.g., ASHRAE Standard 90.1-1999).
- The baseline does not have to comply with performance compliance methods that require the project site to meet an energy budget.
- Demand and energy savings should be calculated with the incorporation of minimum state and federal energy efficiency standards or codes into the determination of baseline energy use.

7.4 Documenting Post-installation Operating Characteristics

To establish the post-installation operating characteristics of the affected systems, the following steps are taken:

1. The Project Sponsor conducts a post-installation equipment survey.
2. EPE and/or its contractor conduct a post-installation inspection.
3. The Project Sponsor conducts any necessary M&V activities.

7.4.1 Post-installation Equipment Survey

The Project Sponsor is required to conduct a post-installation equipment survey to be submitted as part of the Installation Report. The purpose of this equipment survey is to document the equipment that was actually installed as part of a project. For each piece of equipment, the survey should list (as applicable): location, manufacturer, model number, rated capacity, energy use factors (such as voltage, rated amperage, MBtu/hr, wattage), nominal efficiency, the load served, and any independent variables that affect system energy consumption.

7.4.2 Post-installation Inspection

EPE or its contractor will conduct a post-installation inspection to verify that the Project Sponsor has properly documented the installed equipment. After the inspection, EPE will either accept or reject the Installation Report based on the inspection results and project review.

7.4.3 Post-installation Data Collection

After the retrofit, the Project Sponsor must monitor one or both of the following variables simultaneously:

Independent variables that affect energy use. Examples of such data are ambient temperature, control outputs, flow rate, cooling tons, and building occupancy.

System energy consumption. Energy demand (e.g., kW) of the equipment to be affected by the project metered over a representative time period sufficient to document the full range of system operation.

The variable(s) that must be monitored will depend on the savings calculation methodology used for the retrofit, as described further in the next section. Note that the same guidelines for pre-installation data collection should be followed for all post-installation data collection.

7.5 Calculation of Demand and Energy Savings

There are two approaches for calculating demand and energy savings from generic variable load projects. Both approaches require pre- and post-installation metering. The pre-installation metering includes short-term measurements of equipment demand and metering of independent variables. The pre-installation metering is necessary to develop the baseline energy use model.

For the post-installation monitoring, the first approach requires continuous metering of demand and independent variables. The second approach relies on short-term measurements of demand and continuous metering of independent variables. The two methods are summarized below.

1. Short-term, pre-installation metering of demand and independent variables to develop baseline model. Continuous measurement of post-installation demand and the independent variables used in the baseline model. Post-installation variable data are used with the baseline model to calculate baseline energy use.

2. Short-term, pre-installation metering of demand and independent variables to develop baseline model. Short-term, post-installation metering of demand and independent variables to develop post-installation model. Continuous measurement of post-installation variables. Post-installation variable data are used with the baseline and post-installation models to calculate baseline and post-installation energy use.

7.5.1 First Approach: Metering Post-installation Energy Use & Variables

To calculate energy savings using the first approach, the Project Sponsor will monitor demand and the same independent variables that were used to develop the System Baseline Model after installing the project. The Project Sponsor will then compare metered post-installation energy use with pre-installation energy use as estimated by inputting the post-installation monitored independent variables into the System Baseline Model. Demand and energy savings will be calculated using the following equations:

Equation 7.1:

$$\text{Demand Savings [kW]} = kW_{Baseline,Max} - kW_{Measured,Max}$$

Equation 7.2:

$$\text{Energy Savings}_i \text{ [kWh]} = (kW_{Baseline,i} - kW_{Measured,i}) * T_i$$

Equation 7.3:

$$\text{Annual Energy Savings [kWh]} = \text{Sum of (Energy Savings)}_i$$

Where:

$kW_{Baseline,Max}$ = Maximum, pre-installation equipment demand occurring during utility peak, summer, coincident load period.

$kW_{Measured,Max}$ = Maximum, post-installation equipment demand occurring during utility peak, summer, coincident load period.

$kW_{Baseline,i}$ = Baseline kW calculated from Baseline Model and corresponding to same time interval, system output, weather, etc., conditions as $kW_{Measured,i}$.

$kW_{Measured,i}$ = Measured kW obtained through continuous, or representative period, post-installation metering.

T_i = Length of time interval.

7.5.2 Second Approach: Metering Post-installation Variables

To calculate energy savings using the second approach, the Project Sponsor must first develop a Post-Installation System Model for use as a proxy for direct post-installation energy use measurement. Then, the Project Sponsor monitors the relevant independent variables and uses that data to estimate post-installation energy use. Note that the development of the Post-Installation System Model is subject to the same requirements outlined for development of the Baseline System Model. Once the post-installation energy use is estimated, energy savings over the course of a single observation interval will be calculated using the following equations:

Equation 7.4:

$$\text{Demand Savings [kW]} = kW_{Baseline,Max} - kW_{Post\text{-}installation,Max}$$

Equation 7.5:

$$\text{Energy Savings}_i \text{ [kWh]} = (kW_{Baseline,i} - kW_{Post\text{-}installation,i}]) * T_i$$

Equation 7.6:

$$\text{Annual Energy Savings [kWh]} = \text{Sum of (Energy Savings)}_i$$

Where:

$kW_{Baseline,Max}$ = Maximum, pre-installation equipment demand occurring during utility peak, summer, coincident load period.

$kW_{Post\text{-}installation,Max}$ = Maximum, post-installation equipment demand occurring during utility peak, summer, coincident load period.

$kW_{Baseline,i}$ = Baseline kW calculated from Baseline Model and corresponding to same time interval, system output, weather, etc., conditions as $kW_{Post\text{-}installation,i}$.

$kW_{Post\text{-}installation,i}$ = Post-installation kW calculated from Post-Installation Model and corresponding to the measured time interval; measured system output, measured weather variables, etc. in the post-installation period.

T_i = Length of time interval.

For a particular observation interval, the monitored data must be applied to the Baseline System Model and to the Post-Installation Model to determine the baseline-system energy and post-installation system energy input. The modeled-system post-installation is then subtracted from the baseline energy input value. Energy savings are determined by multiplying this difference by the length of the observation interval.

7.6 Project-Specific M&V Issues

Specific M&V issues that need to be addressed for generic variable load projects include:

- Determination of post-installation metering approach -- i.e., monitoring of energy use or post-installation variables.
- Modeling methodology for Baseline System Model(s) and Post-Installation Model (if used).
- How minimum energy efficiency standards will be defined for the Baseline System Model?
- Identification of appropriate variables.
- Duration of baseline and post-installation monitoring.

8 Measurement and Verification Using Billing Analysis and Regression Models

8.1 Overview

Billing analysis involves the use of regression models with historical utility billing data (kW and kWh) to calculate annual demand and energy savings. In general, billing analysis is used with complex equipment retrofits and controls projects. Examples of the types of projects where billing analysis may be employed include the installation of an energy management control system (EMCS), and a comprehensive building retrofit involving multiple types of energy efficiency measures (EEMs).

Billing analysis provides retrofit performance verification for projects where whole-facility baseline and post-installation data are available. Billing analysis usually involves collection of historical whole-facility baseline energy use data and a continuous measurement of the whole-facility energy use after measure installation. Baseline and periodic inspections of the equipment may also be warranted. Energy consumption is calculated by developing statistically representative models (multivariate regression models) of historical whole-facility energy consumption (kWh).

The M&V method described here is based, in part, on Option C of the International Performance Measurement and Verification Protocol (IPMVP). Valuable insights on utility bill analysis can be found in the IPMVP.

8.2 Baseline and Post-Retrofit Data Collection

Collecting and validating data, as well as ensuring alignment of data start and end dates are important elements of billing analysis. Data types and some data analysis protocols are discussed below.

8.2.1 Data Types

As input to the multivariate regression models, billing data provide the basis for calibrating models and post-installation energy use. Site data provide a means for controlling changes in energy use not associated with measure installation. These data elements are discussed below.

Monthly Energy Billing Data. There are typically two types of monthly energy billing data; total energy usage for the month, or energy usage aggregated by time-of-use periods. While either type of data can be used with a regression model, time-of-use is preferable as it provides more insight into usage patterns.

Interval Demand Billing Data. This type of billing data records the average demand for a given interval (e.g., 15 minutes) associated with the billing period.

Site Data. Site data provide the information necessary to account for either changes in or usage of energy consumption that is not associated with the retrofit equipment. Typical site data that can be incorporated in regression models include weather parameters, occupancy, facility square footage and operating hours. These data are typically used to help define the independent variables that explain energy consumption or change associated with equipment other than the equipment installed as part of an EEM.

8.2.2 Data Analysis Protocols

The following are some of the required data analysis protocols:

Baseline Energy Consumption. This regression analysis requires at least 12 months' worth of data prior to the date of installation. However, if energy consumption is sensitive to weather, or other highly variable factors, then at least 24 months worth of data are required.

Post-installation Energy Consumption. This regression analysis requires at least nine months, and preferably twelve months of data after the date of installation to determine impacts for the first year.

Outliers. Outliers are data beyond the expected range of values (e.g., a data point more than two standard deviations away from the average of the data). However, the elimination of outliers should be explained. It is not sufficient to eliminate a data point because it is beyond the expected range of values. If there is reason to believe that the data point is abnormal because of specific mitigating factors, then it can be eliminated from the analysis. Nevertheless, if a reason for the unexpected data point cannot be found, it should be included in the analysis. Outliers should be defined based on "common sense" as well as common statistical practice. Outliers can be defined in terms of consumption changes and actual consumption levels.

8.3 Calculation of Energy Savings: Multivariate Regression Method

Multivariate regression is an effective technique that controls for non-retrofit-related factors that affect energy consumption. If the site data (all relevant explanatory variables, such as weather, occupancy, and operating schedules) are available and/or collected, the technique should result in more accurate and reliable savings estimates than a simple comparison of pre- and post-installation energy consumption.

The use of the multivariate regression approach is dependent on and limited by the availability of site and billing data. The decision to use a regression analysis technique should be based on the availability of this information. Thus, on a project-specific basis, it is critical to investigate the EEM dependent and independent variables that have direct relationships to energy use. Data need to be collected for these variables in a suitable format over a significant period of time.

Separate models may be proposed that define pre-installation energy use and post-installation energy use with savings equal to the difference between the two equations. It is assumed, however, that a single "savings" model will be simpler and generate more reliable estimates since it is also based on more data points.

8.3.1 Overview of the Regression Approach

Regression models should be developed that describe pre-installation and post-installation energy use for the affected site (or sites), taking into account all explanatory variables.

For projects with time-of-use utility billing data, the regression models should yield savings by hour or critical time-of-use period. For projects with only monthly consumption data, the models should be used to predict monthly savings.

8.3.2 Standard Equation for Regression Analysis

In the regression analysis, utility billing data (monthly or hourly) on a project-specific basis are used to develop the models for comparing the pre-installation energy use to post-installation energy use. After adjusting for non-retrofit-related factors in the models, the models' energy use difference is defined as the gross performance impact of the EEMs.

The regression equations should be specified so as to yield as much information as possible about savings impacts. For example, with hourly data, it should be possible to estimate the savings impacts by time of day, day of week, month, and year. With only monthly data, however, it is only possible to determine the effects by month or year. Data with a frequency lower than monthly should not be used under any circumstances.

8.3.3 Independent Variables

Independent variables that affect energy consumption should be specified for use in the regression analysis. These variables can include weather, occupancy patterns, and operating schedules.

If the multivariate regression models discussed above incorporate weather in the form of heating degree-days (HDD) and/or cooling degree-days (CDD), the following issues must be considered:

- The use of the building "temperature balance point" for defining degree-days versus an arbitrary degree-day temperature base.
- The relationship between temperature and energy use that tends to vary depending upon the time of year. For example, a temperature of 55°F in January has a different implication for energy usage than the same temperature in August. Thus, seasonality should be addressed in the model.

8.3.4 Testing Statistical Validity of Models

The statistical validity of the final regression model should be tested by the Project Sponsor and EPE or its contractor and should demonstrate the following:

- The model makes intuitive sense; e.g., the independent variables are reasonable, and the coefficients have the expected sign (positive or negative) and are within an expected range (magnitude).
- The modeled data are representative of the population.

- The form of the model conforms to standard statistical practice.
- The number of coefficients is appropriate for the number of observations (approximately no more than one explanatory variable for every five data observations).
- The T-statistic for all key parameters in the model is at least 2 (95% confidence that the coefficient is not zero).
- The model is tested for possible statistical problems and, if present, appropriate statistical techniques are used to correct for them.
- All data input to the model are thoroughly documented, and model limits (range of independent variables for which the model is valid) are specified.

8.3.5 Compliance with Energy Standards

When using billing analysis methods, the baseline should comply with minimum state and federal energy standards with respect to the following:

- Baseline equipment/systems should not include devices (e.g., lamps and ballasts) that are not allowed to be installed under current regulations.
- Baseline equipment should meet *prescriptive* efficiency standards requirements for affected equipment.
- Surveys and analysis correction methods (potentially outside of the model) should be documented in a project-specific M&V plan.
- The baseline *does not* have to comply with *performance compliance* methods that require the facility to meet an energy budget.

8.3.6 Detailed Calculation Issues

The details of the savings calculations are dependent on such issues as:

- The use of hourly versus monthly utility meter billing data
- The format of the data (e.g., corresponding to same time interval as the billing data) and availability of *all* relevant data for explanatory variables
- The amount of available energy consumption data
- The use of actual or typical data to calculate savings
- Compliance with energy standards when calculating baseline energy use. Energy savings should be calculated with the incorporation of minimum state and federal energy efficiency standards or codes into the determination of baseline energy use.

8.4 Project Specific M&V Issues

When billing analysis methods are used, the project specific M&V plan should address, in addition to other topics generic to all M&V methods, the following:

- How billing data covering an adequate period of time should be used to calculate savings in the performance year?
- How the baseline will be adjusted in order to have the baseline meet minimum energy standards?

9 Measurement and Verification Using Calibrated Simulation Analysis

9.1 Overview

Computer Simulation Analysis for measurement and verification of energy savings is used when the energy impacts of the energy efficiency measures (EEMs) are too complex[7] or too costly to analyze with traditional M&V methods. Situations where computer-based building energy simulations may be appropriate include:

- The EEM is an improvement or replacement of the building energy management or control system.
- There is more than one EEM and the degree of interaction between them is unknown or too difficult or costly to measure.
- The EEM involves improvements to the building shell or other measures that primarily affect the building load (e.g., thermal insulation, low-emissivity windows).

Conducting simulation analysis is a time-consuming task. In some instances, the high costs of conducting simulation analysis may not justify this type of M&V. Also, building simulation software programs are not capable of modeling every conceivable building and equipment or control EEM.

The M&V method described here is based, in part, on Option D of the International Performance Measurement and Verification Protocol (IPMVP). Valuable insights on computer simulation analysis can be found in the IPMVP.

The Project Sponsor should take the following steps in performing Computer Simulation Analysis M&V:

1. Work with EPE and its contractor to define a strategy for creating a calibrated building simulation model in the project-specific M&V plan.
2. Collect the required data from utility bill records, architectural drawings, site surveys, and direct measurements of specific equipment installed in the building.
3. Adapt the data and enter them into the program's input files.
4. Run the simulation program for the "base" building model. The base building is the existing building without the installed EEMs. The base building should comply with minimum state and federal energy standards.

[7] Wolpert, J.S. and J. Stein, "Simulation, Monitoring, and the Design Assistance Professional," 1992 International Energy and Environment Conference.

5. Calibrate the base model by comparing its output with measured data. The weather data for the base model should be the actual weather occurring during the metering period. Refine the base building model until the program's output is within acceptable tolerances of the measured data.
6. Run the calibrated base model using typical weather data to normalize the results.
7. Repeat the process for the post-installation model. Calibration of the retrofit model, if done, should use data collected from site surveys (to validate that all of the equipment and systems are installed and operating properly) and possibly spot, short-term, or utility metering.
8. Estimate the savings. Savings are determined by subtracting the post-installation results from the baseline results using typical conditions and weather. The savings estimates and simulation results will be reviewed and verified by EPE or its contractor.

These steps are described in more detail in the following sections.

9.2 Baseline and Post-Retrofit Data Requirements

9.2.1 Simulation Software

To conduct Calibrated Simulation Analysis M&V, it is recommended that the Project Sponsor use the most current version available of the DOE-2.1E hourly building simulation program. For projects with small projected incentive payments, the Project Sponsor may use other models if the model can be shown to adequately model the project site and the EEMs, can be calibrated to a high level of accuracy, and the calibration can be documented.

9.2.2 Weather Data

Calibrating a computer simulation of a real building for a specific year requires that actual weather data be used in the analysis. Actual weather data should be collected from a source such as National Climatic Data Center (NCDC) weather station data. The physical location of the weather station should be the closest available to the project site. These data should be translated into weather data files that are compatible with DOE-2. The project-specific M&V plan should specify which weather data sources will be used.

Typical weather data used in the calculation of energy savings should be either Typical Meteorological Year (TMY) or TMY2 data types, obtained from the National Renewable Energy Laboratory (NREL).

9.3 Calculation of Energy Savings

9.3.1 Develop a Calibrated Simulation Strategy

The following are issues that either the Project Sponsor or EPE will need to address in order to define the simulation approach:

- **Define the existing building.** In general, the existing building represents the building, as it exists prior to installation of EEMs by the Project Sponsor.

- **Define the baseline building.** The baseline building represents the existing building but with baseline equipment efficiencies as specified by state or federal standards.
- **Define the post-installation building.** The post-installation building represents the building with the project-related EEMs installed.
- **Define the calibration data interval.** The building models should be calibrated using either hourly, daily or monthly data. Calibrations to hourly or daily data are preferred, since they are generally more accurate than calibrations to monthly data because there are more points to compare. If monthly project site billing data are used then spot or short term data collection for calibrated key values may be used.
- **Specify spot and short-term measurements to be taken of building systems.** These measurements augment the whole-building data and enable the modeler to accurately characterize building systems. Spot and short-term measurements are valuable, but may add significant cost and time to the project.
- **Employ an experienced building modeling professional.** Although new simulation software packages make much of the process easier, a program's capabilities and real data requirements are not fully understood by inexperienced users. Employing inexperienced users for this purpose will result in inefficient use of time in data processing, and in checking and understanding of simulation results.

9.3.2 Building Data Collection

The data required for simulating a real building are voluminous. The main categories of data to be collected for the building and proposed EEMs are described below.

- **Building plans.** The Project Sponsor should obtain as-built building plans. If as-built plans are not available, the Project Sponsor should work with the building owner to define alternative sources.
- **Utility bills.** The Project Sponsor should collect a minimum of twelve consecutive months (preferably 24 months), with applicable dates of utility bills for the months immediately before installation of the EEMs. The billing data should include monthly kWh consumption and peak electric demand (kW) for the month. Fifteen minute or hourly data are also desired for calibration. The Project Sponsor should determine if building systems are sub-metered, and collect these data if available. If hourly data are required to calibrate the simulation, but no data are available, metering equipment may need to be installed to acquire hourly data.
- **Conduct on-site surveys.** EPE or its contractor will assist the Project Sponsor to identify the necessary data to be collected from the building. The Project Sponsor should visit the building site to collect the data. EPE or its contractor may accompany the Project Sponsor during the building survey. Data that may be collected include:
  - HVAC systems - primary equipment (e.g. chillers and boilers): capacity, number, model and serial numbers, age, condition, operation schedules, etc.

- HVAC systems - secondary equipment (e.g. air handling units, terminal boxes): characteristics, fan sizes and types, motor sizes and efficiencies, design flow rates and static pressures, duct system types, economizer operation and control
- HVAC system controls, including location of zones, temperature set-points, control set-points and schedules, and any special control features
- Building envelope and thermal mass: dimensions and type of interior and exterior walls, properties of windows, and building orientation and shading from nearby objects
- Lighting systems: number and types of lamps, with nameplate data for lamps and ballasts, lighting schedules, etc.
- Plug loads: summarize major and typical plug loads for assigning values per zone
- Building occupants: population counts, occupation schedules in different zones
- Other major energy consuming loads: type (industrial process, air compressors, water heaters, elevators), energy consumption, schedules of operation, etc.

- **Interview operators.** The Project Sponsor may choose to interview the building operator. Building operators can provide much of the above listed information, and also indicate if any deviation in the intended operation of building equipment exists.
- **Make spot measurements.** The Project Sponsor may find it necessary to record power draw on certain circuits (lighting, plug load, HVAC equipment, etc.) to determine actual equipment operation power.
- **Conduct short-term measurements.** Data-logging monitoring equipment may be set up to record system data as they vary over time. These data reveal how variable load data changes with building operation conditions such as weather, occupancy, daily schedules, etc. These measurements may include lighting systems, HVAC systems and motors. The period of measurement should be from one to several weeks.
- **Obtain weather data.** For calibration purposes, representative site weather data should be obtained for a nearby NCDC site.

9.3.3 Base Building Simulation Models

Once all necessary information is collected, the Project Sponsor should input the simulation data into DOE-2 code to create the base building model. The modeler should refine the model to obtain the best representation of the base building. Where possible, the modeler should use measured data and real building information to verify or replace the program's default values.

9.3.3.1 Minimum energy standards

The baseline model should comply with minimum state and federal energy standards with respect to the following:

- Baseline equipment/systems models should not include devices (e.g. lamps and ballasts) that are not allowed to be installed under current regulations.

- Baseline equipment models should meet *prescriptive* efficiency standards requirements for affected equipment.
- Baseline calculations *do not* have to comply with *performance compliance* methods that require the project site to meet an energy budget.

If the existing conditions of the EEMs do not comply with minimum state and federal standards, the modeler should calibrate the simulation model with the building as it currently exists, and then modify the existing building model to reflect the baseline efficiencies. This modified, or baseline building is then used as the base case for computing energy savings.

9.3.3.2 Calibration

After the base building model has been created and debugged, the modeler should make a comparison of the energy flows and demand projected by the model to that of the measured utility data. All utility billing data should be used in the analysis, electric as well as heating fuels, such as natural gas. The modeler may use either monthly utility bills, or measured hourly data to calibrate the model when available.

The calibration process should be documented to show the results from initial runs and what changes were made to bring the model into calibration. Statistical indices are calculated during the calibration process to determine the accuracy of the model. If the model is not sufficiently calibrated, the modeler should revise the parameters of the model and recalculate the statistics.

9.3.3.3 Hourly data calibration

In hourly calibration, two statistical indices are required to declare a model "calibrated": monthly mean bias error (MBE) and the coefficient of variation of the root mean squared error (CV(RMSE))[8]. MBE is calculated as in Equation 9.1. CV(RMSE) is calculated as in Equation 9.2.

[8] Kreider, J. and J. Haberl, "Predicting Hourly Building Energy Usage: The Great Energy Predictor Shootout: Overview and Discussion of Results," ASHRAE Transactions Technical Paper, Vol. 100, pt. 2, June, 1994; Kreider, J. and J. Haberl, "Predicting Hourly Building Energy Usage: The Results of the 1993 Great Energy Predictor Shootout to Identify the Most Accurate Method for Making Hourly Energy Use Predictions,": ASHRAE Journal, pp. 72-81, March, 1994; Haberl, J. and S. Thamilseran, "Predicting Hourly Building Energy Use: The Great Energy Predictor Shootout II, Measuring Retrofit Savings – Overview and Discussion of Results, ASHRAE Transactions, June, 1996.

Equation 9.1: Monthly mean bias error

$$MBE(\%) = \frac{\sum_{month}(M-S)_{hr}}{\sum_{month} M_{hr}} \times 100$$

Where:

M_{hr}	=	the measured kWh for any hour during the month
S_{hr}	=	the simulated kWh for any hour during the month

Equation 9.2: Coefficient of variation of the root mean squared error

$$CV(RMSE_{month}) = \frac{\sqrt{\sum_{month}(M-S)^2_{hr} * N_{hr}}}{\sum_{month} M_{hr}} * 100$$

Where:

M_{hr}	=	the measured kWh for any hour during the month
S_{hr}	=	the simulated kWh for any hour during the month
N_{hr}	=	the number of hours in the month

The acceptable tolerances for these values when using hourly data calibration are shown in Table 9.1.

Table 9.1: Acceptable tolerances for hourly data calibration

	Value
MBE_{month}	± 10%
$CV(RMSE_{month})$	± 30%

9.3.3.4 Monthly data calibration

Comparing energy use projected by simulation to monthly utility bills is straightforward. First the model is developed and run using weather data that corresponds to the monthly utility billing periods. Next monthly-simulated energy consumption data and actual measured data are plotted against each other for every month in the data set. The error in the monthly and annual energy consumption are calculated by Equation 9.3 and Equation 9.4, respectively.

Equation 9.3: Error in monthly energy consumption

$$ERR_{month}(\%) = \frac{(M - S)_{month}}{M_{month}} * 100$$

Where:

M_{month}	=	the measured kWh for the month
S_{month}	=	the simulated kWh for the month

Equation 9.4: Error in annual energy consumption

$$ERR_{year} = \sum_{year} ERR_{month}$$

The acceptable tolerances for these values when using hourly data calibration are shown in Table 9.2.

Table 9.2: Acceptable tolerances for monthly data calibration

	Value
ERR_{month}	± 25%
ERR_{year}	± 15%

9.3.4 Post-installation models

After measure installation a post-installation model can be prepared. The post-installation model should usually be the baseline model with the substitution of new energy-efficient equipment and systems. This new model should also be calibrated and documented. The possible calibration mechanisms are:

- Using site survey data to validate that all of the specified equipment and systems are installed, have the nameplate data used in the model, and are operating properly.
- Using spot and/or short-term metering data to calibrate particular model modules of equipment, systems or end-uses.

- Using utility (15 minute, hourly or monthly) metering data to calibrate the model, as was done with the pre-installation model.

The above mentioned post-installation model calibration mechanisms are not necessarily mutually exclusive. If the first two mechanisms are used the model can be calibrated soon after measure installation. If the last mechanism is used then the model can only be calibrated after sufficient (e.g., 12 months) billing data are available.

In some instances the post-installation model should be the only model calibrated. This can occur when the baseline project site cannot be easily modeled due to significant changes during the 12 months prior to the new measures being installed and thus the recent billing data are not representative.

9.3.5 Detailed Energy Savings Calculations

Energy savings are determined from the difference between the outputs of the baseline and post-installation models. Savings are determined with both models using the same conditions (weather, occupancy schedules, etc.). To calculate savings, the energy consumption projected by the post-installation model is subtracted from energy consumption projected by the baseline model. Energy savings are calculated with Equation 9.5:

Equation 9.5: Energy savings calculation

$$kWh_{saved} = kWh_{baseline} - kWh_{post}$$

Where:

$kWh_{savings}$	=	The kilowatt-hour savings realized during the year.
$kWh_{baseline}$	=	The kilowatt-hour consumption of the baseline building operating under the same conditions (weather, operation and occupancy schedules, etc.) as the post-installation building.
kWh_{post}	=	The kilowatt-hour consumption of the post-installation building operating under the same conditions (weather, operation and occupancy schedules, etc.) as the baseline building.

9.4 Project-Specific M&V Issues

Specific M&V issues that need to be addressed in the project-specific M&V plan and that are related to this M&V method include:

- Which version of DOE-2 will be used, the supplier of the program, and what if any pre- and post-processors will be used?
- Baseline building description (age square footage, location, etc.) including a description of building systems to be replaced.

- Description of any building operation conditions (set-points, schedules, etc.) that are affected by the EEMs.
- Documentation of compliance for the baseline model with state and federal standards.
- Documentation of the calibrated simulation strategy and project procedure, including differences in calibration parameters between the existing and post-installation cases.
- A summary of the building data to be collected and sources (e.g., site surveys, drawings).
- Identification of spot and short-term measurements to be made.
- Selection of the calibration data interval (should be hourly or monthly).
- Identification and source of weather data used (NCDC weather station or typical weather data).
- Identification of the statistical calibration tolerances and graphical techniques to be used.
- Indication of whom will do the simulation analysis and calibration.
- Specification of format for documentation.

Measurement and Verification Guidelines for New Construction Projects

This section includes detailed information about the measurement and verification (M&V) requirements of the EPE Commercial (COMMERCIAL) Standard Offer Program, as well as guidance for Project Sponsors on how to prepare and execute an M&V plan. These requirements and guidelines are specific to **New Construction** projects.

Introduction to Measurement and Verification for New Construction Projects

Overview

In the El Paso Electric Commercial Standard Offer Program (hereinafter "COMMERCIAL SOP"), the demand and energy savings resulting from a project are determined through measurement and verification (M&V) activities. The M&V methodology appropriate for any given project depends on the equipment type, operational predictability, and project complexity.

Project Sponsors should use the M&V approaches presented here as the basis for developing a methodology for measuring and verifying the demand and energy savings associated with their projects. A Project Sponsor may recommend an alternative approach; however, any alternative must be approved by EPE and adhere to the current *International Performance Measurement and Verification Protocol* (IPMVP), upon which these approaches are based (with the exception of deemed savings approaches, discussed below).

M&V Approaches

The approaches discussed in this section fall into three distinct categories, each of increasing rigor: (1) deemed savings, (2) simplified M&V, and (3) full M&V. The most appropriate approach depends on the availability of evaluation data from previous programs for particular measures, the predictability of equipment operation, and the benefits of the approach relative to the costs associated with that approach.

Deemed Savings

In deemed savings approaches, the demand and energy savings associated with particular measures are based on values stipulated by EPE for factors such as operating hours, efficiencies, and coincidence factors. These values result from analyses of evaluation data from past demand-side management programs or other industry data. The deemed savings approach is appropriate for equipment installations for which savings are relatively certain, such as high efficiency lamps or high performance windows. With deemed savings, the Project Sponsor is not required to perform short-term testing or long-term metering.

Simplified M&V

A simplified M&V approach may involve short-term testing or simple long-term metering, but relies primarily on manufacturer's efficiency data and pre-established savings calculation formulas. Simplified methods can reduce the need for some field monitoring or performance testing. For example, the energy and demand savings associated with a high efficiency chiller would be determined by comparing the rated efficiency of the specified, high-efficiency chiller to that of a standard chiller, and then conducting spot-metering of the chiller's demand and long-term metering of the energy consumption.

Full M&V

In full M&V approaches, demand and energy savings are determined with a greater level of rigor than either the deemed or simplified approaches. Full M&V approaches often involve end-use metering or computer modeling. Any installation that does not meet the criteria for a deemed savings or simplified M&V approach must follow the applicable industry-standard method. Project Sponsors should develop their full M&V methods in accordance with the IPMVP.

Organization of the Guidelines

The M&V approaches discussed in the following chapters cover the majority of equipment types that are installed as part of a new construction project.

Table 1: Organization of M&V chapters

Chapter	Equipment covered	Approaches provided
1	Lamps, ballasts	Deemed and simplified
2	High-Efficiency Cooling Equipment	Simplified
3	High-Efficiency Motors—constant load	Simplified
4	Various (utilizing stipulations)	Deemed and simplified
5	Various (variable load) Equipment	Full
6	Various (utilizing simulation models)	Full

Project Sponsors with specifications for equipment not covered by these M&V chapters should contact EPE for help with creating a custom M&V plan.

Developing Project-Specific M&V Plans

The Project Sponsor should use the chapters in this section, and work with EPE as necessary, to develop an M&V methodology appropriate for the new construction project. The Project Sponsor must document this methodology in an M&V plan, and submit that plan to EPE as part of the Final Application.

At a minimum, a project-specific M&V plan should:

1. Describe the new construction project; include information on how the specified equipment exceeds applicable standards.

2. Identify—by chapter number and title —the approach(es) upon which the M&V methodology is based.

3. Describe the M&V methodology to be used. The methodology description should:

   a. Identify the party responsible for performing M&V activities, including data analysis and documentation of results.

   b. Explain in detail how calculations will be made. For instance, list analysis tools, such as DOE-2 computer simulations, and/or show the equations to be used. A complete method to indicate how collected survey and metering/monitoring data will be used to calculate savings should be defined. All equations should be shown.

   c. Specify what metering equipment will be used, who will provide the equipment, and what the accuracy and calibration will be. Include a metering schedule describing metering times and duration, and how metering data will be validated and reported. Include data formats; electronic, formatted data, read directly from a meter or data logger are recommended for any short or long-term metering.

   d. Define what key assumptions will be made about significant variables or unknowns. For instance: will actual weather data be used, rather than typical-year data? Describe any stipulations that will be made and the source of data for the stipulations.

   e. Describe the sampling methodology: explain why sampling is appropriate, the size of the sample population and how the size is determined, and how sample points are chosen.

4. Explain how quality assurance will be maintained and replication confirmed. For example, will the data being collected be checked every month? Or, to ensure sufficient accuracy, will results be subject to third-party review?

1 M&V Guidelines for New Construction Lighting Efficiency Measures

1.1 Overview

This M&V procedure is intended for use with lighting efficiency measures in new construction projects. Lighting efficiency measures must include the installation of high-efficiency lamps and ballasts. Installed lighting technologies must be at least as efficient as T-8s with electronic ballasts and compact fluorescent light bulbs. T-12s and incandescent light bulbs are not eligible for the program.

This M&V procedure is not intended for use with lighting controls measures. Projects with daylighting controls or occupancy controls measures will be handled on a case-by-case basis. The Project Sponsor should work with EPE to develop appropriate M&V procedures.

Demand savings are based on coincident load factors and a project's installed interior lighting load (Watts), compared to the product of the maximum, code-allowed lighting power density (W/ft^2) for the type of building and the illuminated floor area (ft^2). Energy savings are determined by multiplying the project's demand savings by the average operating hours for the building.

The installed interior lighting load is determined using lighting fixture wattage values from the Table of Standard Fixture Wattages. The Project Sponsor should establish operating hours using one of the following methods:

> **Stipulated Hours Method** – Energy savings are based on whole building stipulated operating hours established for certain building types (See Table 1.2.)
>
> **Metered Hours Method** – Energy savings are determined by metering post-installation operating hours using defined sampling techniques.

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

For lighting efficiency measures installed in spaces conditioned with electric refrigerated air systems, demand and energy savings are also given for lighting-HVAC system interaction. These savings are equal to **10%** of the lighting demand savings and **5%** of lighting energy savings, respectively. Evaporative or alternate fuel system credits for electricity savings must be based on Full M&V results.

In addition to determining operating hours, the Project Sponsor is required to submit a pre-installation equipment specification sheet, detailing the fixtures planned for the building, and a post-installation equipment survey. The Project Sponsor should fill out and submit survey results in the standard New Construction Lighting Equipment Survey using fixture codes provided in the Table of Standard Fixture Wattages. Refer to Chapter 9 (Final

Application) of the Project Sponsor's Manual for an explanation of the Lighting Equipment Survey. EPE or its contractor will conduct a post-installation inspection to verify the installation of the specified equipment.

1.2 Stipulated Hours Method

The procedures outlined below should be followed when the project qualifies for using the stipulated hours M&V approach for lighting efficiency projects. Qualifying projects are those accurately characterized by building types listed in Table 1.2. The Stipulated Hours Method may only be used for those building types listed in Table 1.2, without exception. Buildings of types not listed in Table 1.2 are required to use the Metered Hours Method of M&V (as described in the Overview).

1.2.1 Pre-installation M&V Activities

1.2.1.1 Pre-installation equipment specification

Prior to installing the lighting measures, the Project Sponsor prepares a pre-installation equipment specification sheet by filling out a New Construction Lighting Equipment Survey form. The Project Sponsor submits this information as part of the Final Application. The pre-installation equipment specification should provide the following information about all proposed fixtures: room location, fixture, lamp, and ballast types, area designations, counts of fixtures, and type of control device. Surveys should include all proposed lighting fixtures and controls. The Project Sponsor must include estimates of the amount of lighting that will be provided by task lamps and other moveable lighting sources. Fixture wattages are based on the fixture codes listed in the Table of Standard Fixture Wattages (located in the Program Manual Appendices). This information should be tabulated electronically in the New Construction Lighting Equipment Survey form. Once the Project Sponsor enters all fixtures into the form, the form calculates what the building's installed interior lighting load will be.

Some types of lighting fixtures are exempt from inclusion in the interior lighting demand calculation. Project Sponsors should list exempt fixtures in the separate sheet provided in the New Construction Lighting Equipment Survey form. Exempt fixtures are fixtures that provide lighting that is in addition to general, ambient lighting, have separate control devices, and are installed in one of the following applications [9]:

- Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments.
- Lighting that is integral to equipment or instrumentation and is installed by its manufacturer.
- Lighting specifically designed for use only during medical or dental procedures and lighting integral to medical equipment.
- Lighting integral to both open and glass enclosed refrigerator and freezer cases.
- Lighting integral to food warming and food preparation equipment.
- Lighting for plant growth or maintenance.
- Lighting in spaces specifically designed for use by the visually impaired.

[9] Reference: ASHRAE 90.1-1999, Section 9.3.1.

- Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.
- Lighting in interior spaces that have been specifically designated as a registered interior historic landmark.
- Lighting that is an integral part of advertising or directional signage.
- Exit signs.
- Lighting that is for sale or lighting educational demonstration systems.
- Lighting for theatrical purposes, including performance, stage, and film and video production.
- Athletic playing areas with permanent facilities for television broadcasting.
- Casino gaming areas.
- Lighting that is specifically designated as required by a health or safety statute, ordinance or regulation.
- Guest room lighting in hotels, motels, boarding houses, or similar buildings[10].
- Emergency lighting automatically off during normal building operation[10].

1.2.2 Post-installation M&V Activities

1.2.2.1 Post-installation equipment survey

The Project Sponsor is required to conduct a post-installation lighting equipment survey as part of the Installation Report. The purpose of the post-installation equipment survey is to inventory the actual, as-built equipment. Inventory information should be tabulated electronically in the New Construction Lighting Equipment Survey. Fixture wattages shall be based on the Table of Standard Fixture Wattages. Once the Project Sponsor enters all fixtures into the Survey form, the form calculates the building's installed interior lighting load.

1.2.2.2 Post-installation inspection

EPE or its contractor will conduct a post-installation inspection to verify that the measures were installed as reported. In most cases, EPE or its contractor will inspect statistically significant samples taken from the entire lighting population. The criterion for acceptance is that the error in the installed demand of the sample must be within ±5% of the demand reported on the post-installation lighting equipment inventory form. If the error exceeds ±5%, EPE will inform the Project Sponsor that the submitted lighting survey must be corrected and resubmitted, citing the major cause of the errors found.

1.2.2.3 Lighting power allowance

Demand savings are based on the difference between a project's installed lighting load, compared to the maximum, code-specified lighting power allowance. To calculate the maximum code-allowed lighting power allowance for a building, multiply the maximum lighting power density for the appropriate building type, as listed in Table 1.1, by the gross lighted floor area of the building. If a lighting measure is planned for a building type not

[10] Reference: International Energy Conservation Code (IECC) 2000, Section 805.4.1

listed in Table 1.1, choose the building type that is most similar in function. If a lighting measure is planned for a building with mixed usages, e.g. a high rise building with retail space and office space, choose the building type that represents the largest portion of the floor space.

Table 1.1 Lighting Power Densities by Building Type[11]

Building Type	Lighting Power Density (W/ft^2)		Building Type (cont.)	Lighting Power Density (W/ft^2)
Automotive facility	1.5		Museum	1.6
Convention Center	1.4		Office	1.3
Court House	1.4		Parking Garage	0.3
Dining: Bar Lounge/Leisure	1.5		Penitentiary	1.2
Dining: Cafeteria/Fast Food	1.8		Performing Arts Theater	1.5
Dining: Family	1.9		Police/Fire Station	1.3
Dormitory	1.5		Post Office	1.6
Exercise Center	1.4		Religious Building	2.2
Gymnasium	1.7		Retail	1.9
Hospital/Health Center	1.6		School/University	1.5
Hotel	1.7		Sports Arena	1.5
Library	1.5		Town Hall	1.4
Manufacturing Facility	2.2		Transportation	1.2
Motel	2.0		Warehouse	1.2
Motion Picture Theater	1.6		Workshop	1.7
Multi-Family	1.0			

1.2.2.4 Operating hours

The **Stipulated Hours Method** uses pre-calculated annual operating hours and coincidence factors as listed in Table 1.2. If this table does not accurately characterize the building type, then the Project Sponsor should refer to the **Metered Hours Method** section for the appropriate M&V techniques for measuring operating hours for lighting efficiency measures.

[11] Reference: ASHRAE 90.1-1999, Table 9.3.1.1.

Table 1.2: Stipulated Operating Hours, Coincidence Factors, and Interactive Savings

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

The first column in Table 1.2 presents the stipulated, whole-building, annual operating hours for the building types listed. The energy savings are determined from the operating hours and the kW reduction determined from the New Construction Lighting Equipment Survey form. The average on-peak demand coincidence factor (CF) in the second column is the ratio of the average on-peak operating hours of all lighting circuits to the total number of on-peak hours during the monitoring period. The demand savings are determined from the CF in column two and the kW reduction determined from the Table of Standard Fixture Wattages.

1.2.3 Calculation of Demand and Energy Savings

The peak demand savings and energy savings are calculated according to Equations 1.1 through 1.6. Demand savings are only allowed for lighting fixtures that will be in operation on weekdays between the hours of 1 PM and 7 PM during the months of May through September. Total demand savings are calculated by multiplying the kW savings by the CF for the appropriate building type, from Table 1.2. The CF is used to adjust total installed lighting demand for the actual percentage of fixtures operating during EPE's peak demand hours. The CF is also applied to the interactive savings since interactive savings are a direct result of lighting operation.

Interactive HVAC demand and energy savings may be calculated only for lighting installations that occur in electric, refrigerated air-conditioned spaces. Lighting measures installed in unconditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments. For eligible projects, the interactive HVAC demand savings is a fixed percentage set at **10%** of the lighting demand savings. Similarly, the interactive HVAC energy savings is fixed and equal to **5%** of the lighting energy savings. Evaporative or alternate fuel system interactive credits must be demonstrated through an approved full measurement and verification approach.

1.2.3.1 Peak Demand Savings

Equation 1.1:

Connected Lighting Load Reduction [kW]	**=**	**(Lighting Power Density [W/ft^2] * Gross Lighted Floor Area [ft^2] * .001 [kW/W]) – Installed Interior Lighting Load [kW]**

Equation 1.2:

Interactive HVAC Demand Savings [kW]	**=**	**Connected Lighting Load Reduction [kW] * 0.10**

Equation 1.3:

Total Demand Savings [kW]	**=**	**(Connected Lighting Load Reduction [kW] + Interactive HVAC Demand Savings [kW]) * Coincidence Factor**

1.2.3.2 Energy savings

Equation 1.4:

Lighting Energy Savings [kWh]	**=**	**Connected Lighting Load Reduction [kW] * Annual Operating Hours [hrs]**

Equation 1.5:

Interactive HVAC Energy Savings [kWh]	**=**	**Lighting Energy Savings [kWh] * 0.05**

Equation 1.6:

Total Energy Savings [kWh]	**=**	**Lighting Energy Savings [kWh] + Interactive HVAC Energy Savings [kWh]**

1.2.4 Example

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

Example

High efficiency lighting systems are proposed for a small office building project scheduled for construction in the next year. The office building will have a gross lighted floor area of 70,251 ft^2. The Project Sponsor submits the lighting equipment specification sheet as part of the Final Application, detailing the proposed equipment. The table below summarizes the proposed interior lighting load for each usage group in the project. The code-specified maximum lighting power density for offices is 1.3 W/ft^2. The CF for office buildings is **80%**.

Area Description	Survey Lines[12]	Proposed Interior Lighting Load (kW)	Stipulated Operating Hours
Hallways and Stairs	20	2.0	3,760
Common Offices	72	14.4	3,760
Conference Rooms	20	9.6	3,760
Task Lamps	24	4.8	3,760
Private Offices	44	41.2	3,760
Restrooms	20	2.8	3,760
Total	**200**	**74.8**	

Based on the collected data, the demand and energy savings are calculated:

(a) Connected Lighting Load Reduction = (1.3 W/ ft^2 * 70,251 ft^2 * .001 kW/W) – 74.8 kW
= 16.5 kW.

(b) Interactive HVAC Demand Savings = 16.5 kW * 0.10
= 1.7 kW.

(c) Total Demand Savings = (16.5 kW + 1.7 kW) * 0.80
= 14.6 kW.

(d) Lighting Energy Savings = 14.6 kW * 3,760 hours
= 54,896 kWh.

(e) Interactive HVAC Energy Savings = 54,896 kWh * 0.05
= 2,745 kWh.

(f) Total Energy Savings = 54,896 kWh + 2,745 kWh
= 57,641 kWh.

[12] For a description of *Survey Lines*, refer to Section 1.3 to follow.

1.3 Metered Hours Method

The **Metered Hours Method** involves monitoring a statistically significant sample of fixtures to determine post-installation operating hours. This involves developing a sampling plan to monitor the average operating hours for each lighting usage group. The Project Sponsor should conduct all meter installation, retrieval and data analysis.

1.3.1 Pre-installation M&V Activities

1.3.1.1 Pre-installation equipment survey

Prior to installing the lighting measures, the Project Sponsor prepares a pre-installation equipment specification sheet by filling out a New Construction Lighting Equipment Survey form. The Project Sponsor submits this information as part of the Final Application. The pre-installation equipment specification should provide the following information about all proposed fixtures: room location, fixture, lamp, and ballast types, area designations, counts of fixtures, and type of control device. Surveys should include all proposed lighting fixtures and controls. The Project Sponsor must include estimates of the amount of lighting that will be provided by task lamps, lamps integral to office furniture, and Fixture wattages are based on the fixture codes listed in the Table of Standard Fixture Wattages. This information should be tabulated electronically in the New Construction Lighting Equipment Survey (see Chapter 9 of the COMMERCIAL Program Manual for an explanation). Once the Project Sponsor enters all fixtures into the form, the form calculates what the building's installed interior lighting load will be.

Some types of lighting fixtures are exempt from inclusion in the interior lighting demand calculation. Project Sponsors should list exempt fixtures in the separate sheet provided in the New Construction Lighting Equipment Survey form. Exempt fixtures are fixtures that provide lighting that is in addition to general, ambient lighting, have separate control devices, and are installed in one of the following applications[13]:

- Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments.
- Lighting that is integral to equipment or instrumentation and is installed by its manufacturer.
- Lighting specifically designed for use only during medical or dental procedures and lighting integral to medical equipment.
- Lighting integral to both open and glass enclosed refrigerator and freezer cases.
- Lighting integral to food warming and food preparation equipment.
- Lighting for plant growth or maintenance.
- Lighting in spaces specifically designed for use by the visually impaired.
- Lighting in retail display windows, provided the display area is enclosed by ceiling-height partitions.

[13] Reference: ASHRAE 90.1-1999, Section 9.3.1.

- Lighting in interior spaces that have been specifically designated as a registered interior historic landmark.
- Lighting that is an integral part of advertising or directional signage.
- Exit signs.
- Lighting that is for sale or lighting educational demonstration systems.
- Lighting for theatrical purposes, including performance, stage, and film and video production.
- Athletic playing areas with permanent facilities for television broadcasting.
- Casino gaming areas.
- Lighting that is specifically designated as required by a health or safety statute, ordinance or regulation.
- Guest room lighting in hotels, motels, boarding houses, or similar buildings[14].
- Emergency lighting automatically off during normal building operation[14].

1.3.1.2 Usage groups

When compiling the equipment specification form, Project Sponsors should organize the equipment into **usage groups—**collections of equipment (e.g., rooms with lighting fixtures) with similar operating schedules and functional uses. For instance, although a site's restroom lighting may have the same annual hours of operation as the open office lighting, the two have different functional uses and should be classified in separate usage groups. Please refer to Table 1.3 to determine the recommended minimum number of usage groups for the project site type.

[14] Reference: International Energy Conservation Code (IECC) 2000, Section 805.4.1

Table 1.3: Suggested minimum numbers of Usage Groups for project site types

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

1.3.2 Post-installation M&V Activities

1.3.2.1 Post-installation equipment survey

The Project Sponsor is required to conduct a post-installation lighting equipment survey as part of the Installation Report. The purpose of the post-installation equipment survey is to inventory the actual, as-built equipment. Inventory information should be tabulated electronically in the New Construction Lighting Equipment Survey. Fixture wattages shall be based on the Table of Standard Fixture Wattages.

1.3.2.2 Post-installation inspection

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

1.3.2.3 Post-Installation operating hours

After the lighting equipment has been installed and the facility is occupied, the Project Sponsor conducts short-term metering of the operating hours for a random sample of fixtures in each usage group. As part of the Final Application review and approval, EPE or their contractor can assist the Project Sponsor to randomly select the population of fixtures to be metered.

1.3.2.4 Metering requirements

For facilities with little variation in weekly operating schedules (such as offices), monitoring shall be conducted for each selected circuit for a recommended minimum of **two to four**

weeks during the entire year. Monitoring should not be installed during significant holidays or vacations. If a holiday or vacation falls within the monitoring period, the duration should be extended for as many days as that holiday or vacation. For facilities such as schools, where operating hours vary seasonally, monitoring should be conducted for a minimum period during each season (i.e., in-session [fall], and out-of-session [summer]). In these cases, one of the monitoring periods should depict typical performance during the peak-demand period.

A *Survey line*, or last point of control (LPC), is a distinct portion of an electrical circuit serving a set of equipment that is controlled on a single switch. So if a project involves a *Hallways and Stairs* usage group that has 20 survey lines or LPCs, such as the previous *Example* in Section 1.2.4, it means there are 20 separate circuits in those like areas controlled at a switch (Two or more switches controlling the same circuit would still be just one survey line).

Table 1.4 shows the required minimum number of circuits to randomly sample depending on a usage group's survey line population; note that, because lighting loggers sometimes fail, over-sampling is strongly recommended. Light loggers should be tested and calibrated prior to installation to verify that the light loggers are functioning properly.

Table 1.4: Monitoring sample sizes*

Population of Survey Lines in Usage Group (n)	Sample Size
n≤4	All
5	4
6≤n<9	5
9≤n<14	6
14≤n<20	7
20≤n<34	8
34≤n<68	9
68≤n<386	10
n≥386	11

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

1.3.2.5 Calculation of average operating hours

The Project Sponsor should extrapolate results from the monitored sample to the population to calculate the average lighting operating hours for every unique usage group. Simple, unweighted averages of operating hours should be calculated for each usage group using Equation 1.7. The Project Sponsor should use these average operating hours to calculate the energy savings for each respective usage group.

Equation 1.7: Calculation of annual operating hours for a usage group

$$Hours_{annual,u} = \frac{\sum_{i=1}^{n}\left[\frac{Hours_{on,i}}{Hours_{metered,i}} * 8{,}760\ {}^{hours}/_{year}\right]}{n}$$

Where:

$Hours_{annual,u}$	=	Average annual operating hours for usage group *u*
$Hours_{on,i}$	=	Operating hours observed during the metering period for circuit *i*
$Hours_{metered,I}$	=	Total number of hours in the metering period for circuit *i*
n	=	Number of metered circuits in usage group *u*

After calculating annual operating hours for each usage group, the Project Sponsor can calculate annual operating hours for the whole building. The annual operating hours for the whole building are equal to the average of the operating hours for each usage group, weighted by the installed lighting demand of each usage group.

Similarly, Equation 1.8 illustrates the calculation of average on-peak demand coincidence factor (CF) for a usage group. The CF multiplied by the difference in baseline and post-installation demand for each usage group, determined from the Table of Standard Fixture Wattages, gives the calculate demand savings. Demand savings are only allowed for lighting fixtures that will be in operation on weekdays between the hours of 1 PM and 7 PM during the months of May through September.

Equation 1.8: Calculation of coincidence factor for a usage group

$$CF_u = \frac{\sum_{i=1}^{n}\left[\frac{Hours_{peak\,on,i}}{Hours_{peak\,metered,i}}\right]}{n}$$

Where:

CF_u	=	Peak-demand coincidence factor for usage group *u*
$Hours_{peak\ on,i}$	=	Equipment on-hours observed during the peak demand period during the metering period for circuit *i*
$Hours_{peak\ metered,i}$	=	Total number of peak demand hours in the metering period for circuit *I*
n	=	Number of metered circuits in usage group *u*

After calculating coincidence factors for each usage group, the Project Sponsor can calculate an average coincidence factor for the whole building. The coincidence factor for the whole building is equal to the average of the coincidence factors for each usage group, weighted by the installed lighting demand of each usage group.

1.3.3 Calculation of Demand and Energy Savings

The peak demand savings and energy savings are calculated according to Equations 1.1 through 1.6, and Equations 1.9 and 1.10 below. The hours of operation should be calculated for each usage group and also for each season in which the usage groups' operating hours may vary (as for schools). The annual hours of operation are determined by adding together the operating hours that are calculated for each season. If the operating hours do not vary seasonally, use one year as the "season". If the operating hours do not vary seasonally, use one year as the "season". Interactive HVAC demand and energy savings may be calculated using deemed savings multipliers only for lighting retrofits taking place in spaces air-conditioned with electric refrigerated air systems. Lighting retrofits in unconditioned spaces, such as parking garages, are not eligible for interactive HVAC savings payments. For eligible projects, the interactive HVAC demand savings is a fixed percentage set at 10% of the lighting demand savings. Similarly, the interactive HVAC energy savings is fixed and equal to 5% of the lighting energy savings. A Project Sponsor may propose and demonstrate electric energy and demand savings for evaporative or gas air conditioning systems using a full measurement and verification approach.

1.3.3.1 Hours of Operation (see Equation 1.7 above)

Equation 1.8:

$$\text{Seasonal Hours of Operation [hrs]} = \frac{\text{Hours Lights On}}{\text{Hours Lights Metered}} * \text{Hours in Season}$$

Equation 1.9:

$$\text{Annual Hours of Operation [hrs]} = \text{Sum of } \{\text{Seasonal Hours of Operation [hrs]}\}$$

1.3.3.2 Peak demand savings

Peak demand savings are calculated using Equations 1.1, 1.2, and 1.3.

1.3.3.3 Energy savings

Energy savings are calculated using Equations 1.4, 1.5, and 1.6.

1.3.4 Example

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

Example

A 57,800 ft^2, 24-hour warehouse was constructed with highly efficient lighting systems. The Project Sponsor submits the Lighting Equipment Survey as part of the Installation Report, detailing the installed equipment. The following table summarizes the connected lighting load (including calculated Coincidence Factors) for each usage group in the project, as well as the metering results. In this example. The operating hours are metered according to the required sample sizes for each usage group in the project. Because there is only one operating season, the light loggers are installed for one three-week period. The operating hours for each usage group are the average of observed operating hours from all meters.

Area Description	Connected Lighting Load (kW)	Measured Operating Hours	Measured Coincidence Factor
Receiving	2.0	[188/504] * 8,760 =3,268	[19/75] = 0.25
Admin. Offices	14.4	[106/504] * 8,760 = 1,842	[23/75] = 0.31
Restrooms	9.6	[225/504] * 8,760 = 3,911	[38/75] = 0.51
Shop	4.8	[314/504] * 8,760 = 5,458	[44/75] = 0.59
Continuous	41.2	[410/504] * 8,760 = 7,126	[60/75] = 0.80
Total	**72.0**	**Weighted Avg. = 5,422**	**Weighted Avg. = 0.63**

Based on the collected data, the demand and energy savings are calculated:

(a) Connected Lighting Load Reduction = (1.9 W/ ft^2 * 57,800 ft^2 * .001 kW/W) – 72.0 kW
= 37.8 kW.

(b) Interactive HVAC Demand Savings = 37.8 kW * 0.10
= 3.8 kW.

(c) Total Demand Savings = (37.8 kW + 3.8 kW) * 0.63
= 26.2 kW.

(d) Lighting Energy Savings = 37.8 kW * 5,422 hours
= 204,952 kWh.

(e) Interactive HVAC Energy Savings = 204,952 kWh * 0.05
= 10,247 kWh.

(f) Total Energy Savings = 204,952 kWh + 10,247 kWh
= 215,199 kWh.

2 Simplified M&V Guidelines for High-Efficiency Cooling Equipment

2.1 Overview

Cooling equipment retrofits involve the installation of equipment that exceeds current energy efficiency standards. This chapter presents both a deemed savings approach and a simplified approach to the measurement and verification of savings from the installation of more efficient cooling equipment. In general, the measurement and verification (M&V) methods described in this chapter can only be used for projects involving the one-for-one substitution of cooling equipment. Potential qualifying equipment includes:

- Unitary air conditioners (DX, air-cooled, evaporative, or water-cooled)
- Heat pumps (air-cooled, evaporative, or water-cooled)
- Chillers (air-cooled centrifugal, water-cooled centrifugal, air-cooled screw)
- Compressors (centrifugal, screw, reciprocating)

The projects should have the following characteristics:

- Documented cooling load calculations for the affected facility.
- Not be including the effects of building systems or other equipment as factors in their savings calculations.

If the project does not meet these requirements, please refer to Chapter 5 or Chapter 6 for the appropriate M&V approach.

The applicable baseline efficiency values are from ASHRAE Standard 90.1-1999; these values are provided in the Standard Cooling Equipment Tables in Appendix A of this document. The applicable column in the Standard Cooling Equipment Tables is titled "Minimum Performance Standard".

2.2 Deemed Savings for Cooling Equipment

The *deemed savings* approach to M&V for cooling equipment is only applicable to one-for-one equipment substitution in new construction.

Projects that are eligible to use the deemed savings approach meet the following requirements:

- The installed cooling equipment is electric.
- The Project Sponsor and EPE agree on the correct climate zone to use for the calculation.
- Coefficients are listed in Table A.10 of Appendix A for the type of building in which the project occurs and the type of equipment involved.
- The building falls into one of the categories described in Table 2.1.

Table 2.1: Building descriptions for use in the air-conditioning equipment deemed savings M&V methodology

Building Type	Description
Religious Worship	A religious worship building that experiences full operation on Sundays, and a partial schedule on weekdays and Saturdays.
College	A multi-story college building that operates a full day five days per week and a partial day on weekends.
Convenience	A small convenience store that operates 24 hours per day, 7 days per week.
Fast-Food	A small fast food restaurant that operates a full day, seven days per week. Generally smaller than 3,000 sq. ft.
Grocery	Typical supermarket that operates between 16 and 24 hours per day, 7 days per week.
Hospital	A multi-story hospital building that operates 24 hours per day, 7 days per week.
Hotel	A typical multi-story hotel that operates 24 hours per day, 7 days per week. Usually larger than 50,000 sq. ft.
Motel	A low-rise motel that operates 24 hours per day, 7 days per week. Usually smaller than 50,000 sq. ft.
Nursing Home	An assisted care facility that operates 24 hours per day, 7 days per week.
Office, Large	Typical multi-story office building that operates 12 to 16 hours per day, Monday through Friday, a half-day on Saturday and a few hours on Sunday. Applicable for buildings greater than 50,000 sq. ft.
Office, Small	Typical low-rise office building that is operated mostly Monday through Friday and a minimal number of hours on Saturday and Sunday. Applicable for buildings up to 50,000 sq. ft.
Public Assembly	A large public assembly building that operates on a partial schedule all days.
Retail	Retail store that operates typical business hours Monday through Saturday and a reduced day on Sundays.
Restaurant	Typical small restaurant operating full day six days per week with a reduced schedule on Sundays. Generally larger than 3,000 sq. ft.
School	A low-rise elementary or high school that operates all day Monday through Friday, 50 weeks per year.
Service	A light commercial building that operates a full day six days per week. Examples include beauty parlors, automotive shops and so on.
Warehouse, Non-Refrig.	A conditioned warehouse, not refrigerated, that operates 24 hours/ day, 7 days per week.

Table A.10 of Appendix A does not list coefficients for every type of cooling equipment in every building type. For example, the deemed savings M&V approach is not available for water-cooled chillers for small building types such as convenience stores and fast food restaurants because water-cooled chillers are uncommon in these types of buildings.

2.2.1 Pre-Installation M&V Activities

2.2.1.1 Pre-installation Site Survey

A pre-construction site inspection is generally not required, but in some cases – such as projects involving additions to existing facilities – this inspection may be requested at the utility Program Administrator's request.

The baseline efficiency for savings measurement is the minimum efficiency listed in the Standard Cooling Equipment Tables, which are based on ASHRAE 90.1-1999, provided in Appendix A in the *Appendices to M&V Guidelines* found at the end of this document.

2.2.2 Post-Installation M&V Activities

2.2.2.1 Post-installation Equipment Survey

Once the construction project is complete, the Project Sponsor conducts and submits a post-installation equipment survey as part of the Installation Report (IR). The survey should include: installed equipment type, year, make/model, rated capacity, and rated efficiency. The cooling equipment description and its location should be included with the IR submittal.

The Project Sponsor must submit manufacturer's documentation of the rated efficiency of all installed cooling equipment, based upon Air-Conditioning and Refrigeration Institute (ARI)[15] test conditions. This documentation will be in the form of manufacturer cut sheets or factory performance test results that document the part load performance of the equipment.

2.2.2.2 Post-installation Inspection

EPE or its contractor will conduct a post-installation inspection to verify that the equipment was installed as reported and is documented accurately.

2.2.3 Deemed Savings Calculations

The deemed savings methodology involves the application of two mathematical equations shown in Equation 2.1 and Equation 2.2.

[15] The Air-Conditioning and Refrigeration Institute (ARI) is the national trade association representing manufacturers of more than 90 percent of North American produced central air-conditioning and commercial refrigeration equipment (www.ari.org). As one of its most important functions, ARI develops and publishes technical standards for industry products. ARI standards establish rating criteria and procedures for measuring and certifying product performance.

Equation 2.1: Calculation of peak demand savings for cooling equipment

$$kW_{savings} = Tons * (a \cdot \eta_{baseline} - b \cdot \eta_{post\text{-}installation})$$

Where:

$kW_{savings}$	=	Calculated demand savings
$Tons$	=	the rated equipment cooling capacity at ARI standard conditions
a	=	The demand coefficient from Table A.10 in the Appendix for the appropriate climate zone, building type and baseline equipment type.
$\eta_{baseline}$	=	Efficiency of the baseline equipment (kW/Ton)
b	=	The demand coefficient from Table A.10 in the Appendix for the appropriate climate zone, building type and retrofit equipment type.
$\eta_{post\text{-}installation}$	=	Rated efficiency of the installed equipment (kW/Ton)

Equation 2.2: Calculation of energy savings for cooling equipment

$$kWh_{savings} = Tons * (c \cdot \eta_{baseline} - d \cdot \eta_{post\text{-}installation})$$

Where:

$kWh_{savings}$	=	Calculated energy savings
$Tons$	=	the rated equipment cooling capacity at ARI standard conditions
c	=	The energy coefficient from Table A.10 in the Appendix for the appropriate climate zone, building type and baseline equipment type.
$\eta_{baseline}$	=	Efficiency of the baseline equipment (kW/Ton)
d	=	The energy coefficient from Table A.10 in the Appendix for the appropriate climate zone, building type and retrofit equipment type.
$\eta_{post\text{-}installation}$	=	Rated efficiency of the installed equipment (kW/Ton)

To calculate savings for cooling equipment retrofits using the deemed savings methodology, follow these steps:

1. Determine the applicable baseline efficiency for the existing equipment in kW/ton (η_{baseline}). Record the minimum baseline efficiency (ASHRAE 90.1-1999).

   Use the following conversions to get kW/Ton where necessary[16]:

   kW/ton = 12 / EER

   kW/ton = 3.516 / COP

   kW/ton = 12 / (SEER*0.697 + 2.0394)

2. Determine the applicable efficiency for the new equipment in kW/ton ($\eta_{\text{post-installation}}$).

3. Determine the applicable equipment capacity (*Tons*). Record the unit tonnage.

4. Determine the applicable demand and energy coefficients (*a, b, c,* and *d*). The equipment will be of the same type and technology, so a = b and c = d. Go to the Table A.10 in Appendix A. Look up the demand and energy coefficients for the appropriate building and equipment type.

5. Use equations 2.1 and 2.2 to calculate peak demand and energy savings.

[16] The conversion from SEER to kW/ton is an approximation based on published data from the Carrier Corporation

Example

A 150-ton air-cooled packaged unit (with electric resistance heat) in a retail application is being replaced with a more efficient unit (of similar size and type) in El Paso.

Step 1 The Project Sponsor finds the appropriate baseline efficiency (this equates to the Minimum Performance Standard when it is a New Construction project) from Appendix A, Table A.6. A 150-ton air-cooled packaged unit has an EER of 9.2. Using the conversion, kW/Ton = 12/EER, the Project Sponsor finds that η_{baseline} = 1.30 kW/Ton.

Step 2 The manufacturer's data for the new equipment shows that the EER = 10.5. Using the conversion, kW/Ton = 12/EER, the Project Sponsor finds that $\eta_{\text{post-installation}}$ = 1.14 kW/Ton.

Step 3 The existing and new packaged units are each 150-ton units.

Step 4 The Project Sponsor looks in Appendix A, Table A.10 to find the appropriate coefficients. The demand coefficient for a retail building with a DX air-cooled unit in El Paso is 0.92, so $a = b$ = 0.92. The energy coefficient for a retail building with a DX air-cooled unit in El Paso is 2,225, so $c = d$ = 2,225.

Step 5 By inserting the information gathered in Steps 1-4 into Equations 3.1 and 3.2, the Project Sponsor calculates the savings:

$$kW_{savings} = 150 * (0.92 * 1.30 - 0.92 * 1.14) = 22.5 \text{ kW}$$

$$kWh_{savings} = 150 * (2{,}225 * 1.30 - 2{,}225 * 1.14) = 53{,}400 \text{ kWh}$$

2.3 Simplified M&V – Limited Measurement

The simplified M&V procedure for electric-to-electric cooling equipment involves collecting one year of consumption data after the project is complete. To determine demand savings, the maximum equipment demand that occurs during the utility peak summer hours must be measured. This can be accomplished with continuous demand metering or spot metering during peak conditions.

2.3.1 Pre-Construction M&V Activities

2.3.1.1 Equipment Survey

As part of the application process, the Project Sponsor provides an inventory of *all* specified cooling equipment for buildings with a central plant.

The information provided should include;

- equipment type
- year
- make/model
- rated capacity
- rated efficiency

- operating schedule
- operating sequence

2.3.1.2 Site Inspection

A pre-construction site inspection is generally not required, but in some cases—such as projects involving additions to existing facilities—this inspection may be requested at EPE's discretion.

2.3.2 Post-Installation M&V Activities

2.3.2.1 Equipment Survey

After construction is complete, the Project Sponsor provides a post-construction equipment inventory to EPE as part of the Installation Report (IR). This survey must include the same information itemized above, and be accompanied by a description of the cooling equipment and its location as well as mechanical design drawings.

The Project Sponsor also submits manufacturer documentation of the rated efficiency of all installed cooling equipment, based on ARI test conditions. This documentation should be in the form of manufacturer cut sheets or factory performance test results that show the part load performance of the equipment.

2.3.2.2 Site Inspection

Either EPE or its contractor conducts a post-construction inspection to verify that the specified equipment has been installed as reported and has been documented accurately.

2.3.2.3 Performance Monitoring

To verify the energy consumption (kWh) impacts of the higher efficiency cooling equipment, the Project Sponsor collects consumption data, continuously, for a 12-month period. To verify the impacts on demand (kW), the Project Sponsor measures demand for a one-hour period either through continuous demand metering (at 15-minute intervals) or with spot measurements, conducted between the hours of 1 PM and 7 PM on weekdays during the months of May through September.

2.3.3 Calculation of Demand and Energy Savings

2.3.3.1 High Efficiency Cooling Equipment

Project Sponsors can claim demand savings only for equipment that operates on weekdays between the hours of 1 PM and 7 PM, Monday through Friday, during the months of May through September.

Peak demand and energy savings are calculated according to Equation 2.1 and Equation 2.2, respectively.

Equation 2.1 Peak Demand Savings

$$\Delta kW = kW_{meter} \cdot \left\{ \left[\frac{COP_{new}}{COP_{base}} \right] - 1 \right\}$$

Where:

kW_{meter}	=	Maximum 15-minute cooling equipment demand measured during the utility peak demand period.
COP_{new}	=	High-efficiency cooling equipment coefficient-of-performance (COP) at ARI design conditions.
COP_{base}	=	Baseline efficiency for baseline cooling equipment from Appendix A.

Equation 2.2 Energy Savings

$$\Delta kWh = kWh_{meter} \cdot \left\{ \left[\frac{COP_{new}}{COP_{base}} \right] - 1 \right\} * \left(\frac{CDD(65)_{TMY}}{CDD(65)_{meter}} \right)$$

Where:

kWh_{meter}	=	Summed metered kWh cooling equipment energy use determined for one year.
COP_{new}	=	High-efficiency cooling equipment coefficient-of-performance (COP) at ARI design conditions.
COP_{base}	=	Baseline efficiency for baseline cooling equipment from Appendix A.
$CDD(65)_{TMY}$	=	Cooling degree days (base 65 F) for a typical meteorological year (TMY) for the National Climatic Data Center (NCDC) station nearest the site. The value is available in Appendix A, Table A.9.
$CDD(65)_{meter}$	=	Cooling degree days (base 65 F) determined for the metering period for the National Climatic Data Center (NCDC) station nearest the site. The value is determined by EPE based on the metering period start and stop dates using monthly CDD (65) data available from the NCDC at http://lwf.ncdc.noaa.gov/oa/ncdc.html.

Example

For an El Paso office building, a 600-ton, water-cooled, high-efficiency electric centrifugal chiller is specified. The high-efficiency chiller has an ARI-rated COP of 6.6 (0.530 kW/ton). One year of post-construction metering shows the chiller energy use to be 697,374 kWh. The maximum demand recorded for the chiller during the metering period coincident with EPE's peak demand period is 286 kW.

One year of continuous energy-consumption data was collected. To complete the simple M&V savings calculation, the following information is also needed:

- ASHRAE 90.1-1999 minimum chiller efficiency
- The NCDC station nearest the site
- The NCDC station TMY CDD (65)
- The NCDC station CDD (65) determined for the metering period

From the Standard Equipment Tables, the minimum COP for a water-cooled centrifugal chiller of 300 tons or more is **6.1** (or 0.577 kW/ton). The NCDC weather station is the **El Paso** station. The cooling degree day data for the station are **2094 °F** day for TMY2 and **2078 °F** day for the metering year.

Based on the collected data and system characteristics, the demand savings are determined as follows:

$$\Delta kW = kW_{meter} * \left\{ \left[\frac{COP_{new}}{COP_{base}} \right] - 1 \right\}$$

$$\Delta \mathrm{kW} = 286 * \left\{ \left[\frac{6.6}{6.1} \right] - 1 \right\}$$

The estimated demand savings equal **23.4 kW**.

The energy savings are determined as follows:

$$\Delta kWh_{chiller} = kWh_{meter} * \left\{ \left[\frac{COP_{new}}{COP_{base}} \right]_{rated} - 1 \right\} * \left(\frac{CDD(65)_{TMY}}{CDD(65)_{meter}} \right)$$

$$\Delta \mathrm{kWh} = 697{,}374 * \left\{ \left[\frac{6.6}{6.1} \right] - 1 \right\} * \left(\frac{2{,}094}{2{,}078} \right)$$

The energy savings equal **57,642 kWh**.

3 Simplified M&V Guidelines for Constant Load Motor Measures

3.1 Overview

This chapter presents the simplified M&V approach for projects involving the specification of constant load motors with efficiency ratings higher than those required by the applicable energy efficiency standard. Examples of qualifying equipment include

- Constant load chilled water, hot water, or condenser water pumps
- Constant speed exhaust, return, and supply fans without dampers or pressure controls
- Single-speed cooling tower fans
- Constant load industrial processes
- Similar capacity, constant speed, energy efficiency motors

Project Sponsors *should not* use this approach if factors utilized to derive savings vary throughout the year. Examples may include schedule changes and load changes.

If the project does not meet the above requirements, please refer to Chapter 5 for the appropriate M&V approach.

Demand and energy savings for motor installations are based on post-construction peak demand (kW), the motor operating hours, and the difference in efficiency between baseline and higher-efficiency motors.

The peak demand period is defined as weekdays, between the hours of 1 PM and 7 PM, from May 1 through September 30 (excluding holidays). The operating hours are assumed the same for both baseline and higher-efficiency motors.

Baseline motor efficiencies are listed in the Standard Motor Table in Appendix B of this document, which is based on ASHRAE Standard 90.1m-1995. The Standard Motor Table is categorized by motor size and rotation speed. No incentive payments are made for new motors with efficiencies equal to or less than the respective baseline efficiencies. In addition, all new motors should meet minimum equipment standards as defined by state and federal law.

3.2 Pre-Construction Activities

3.2.1 Equipment Survey

The Project Sponsor provides an inventory of the specified equipment to EPE as part of the Final Application along with motor locations and corresponding facility mechanical plans. At a minimum, the survey should include the following for each high-efficiency motor:

- Motor name
- Load served
- Motor location
- Operating schedule
- Equipment manufacturer
- Nameplate data including model, horsepower, and speed

Site Inspection

A pre-construction site inspection is generally not required, but in some cases—such as projects involving additions to existing facilities—this inspection may be requested at EPE's discretion.

3.3 Post-Construction Activities

3.3.1 Equipment Survey

The Project Sponsor provides a post-construction equipment survey, similar to the pre-construction equipment survey, to EPE as part of the Installation Report. This survey reflects the actual, as-built conditions of the project.

3.3.2 Motor Demand Measurement

The Project Sponsor performs spot measurements of the power draw (one-hour average values) of all the high-efficiency motors installed, and includes these measurements in the Installation Report.

Calculation of Baseline Motor Demand

Equation 3.1 is used to determine what the demand would have been had a lower efficiency motor been specified for installation.

Equation 3.1 Baseline Motor Demand

$$\text{Baseline demand [kW]} = \frac{\text{Specified motor efficiency}}{\text{Baseline motor efficiency}} * \text{Spot-measured motor demand}$$

In Equation 3.1, the specified motor efficiency is obtained from manufacturer's specifications. The baseline motor efficiency should be obtained from the Standard Motor Efficiency Table, in Appendix B of this document.

3.3.3 Site Inspection

After EPE receives a Project Sponsor's Installation Report, either EPE or its contractor conducts a post-construction site inspection to verify that the equipment specifications have been correctly reported by the Project Sponsor in the Installation Report. EPE will require the Project Sponsor to make any necessary corrections to the Installation Report based on the results of the inspection.

3.3.4 Calculation of Motor Operating Hours

After EPE approves the Installation Report, the Project Sponsor begins short-term metering of motor operating hours. The metering must be conducted for a minimum period of one week, or an amount of time sufficient to capture the full range of operation. Equation 3.2 is used to calculate the annual operating hours using the metered data.

Equation 3.2 Motor Operating Hours

$$\text{Annual operating hours [hrs/yr]} = \frac{\text{Motor on-time during metering period (hrs)}}{\text{Length of metering period (hrs)}} * \text{8760 hrs/yr}$$

For constructions in which a large number of equal-sized motors have the same application and operating schedule, metering may be conducted for a sample of motors and the results extrapolated to the applicable population. If such an approach is adopted, EPE will assist the Project Sponsor in selecting the sample motors.

The Project Sponsor should include electronic copies of the unprocessed data files as part of the Savings Report.

Calculation of Peak Demand and Energy Savings

Project Sponsors can claim demand savings only for equipment that operates on weekdays between the hours of 1 PM and 7 PM, Monday through Friday, from May 1 through September 30 (excluding holidays).

Peak demand and energy savings are calculated according to Equation 3.3 and Equation 3.4, respectively.

Equation 3.3 Peak Demand Savings

$$\text{Peak demand savings [kW]} = \text{Baseline motor demand [kW]} - \text{Spot-measured motor demand [kW]}$$

Equation 3.4 Energy Savings

$$\text{Energy savings [kWh]} = \text{Peak demand savings [kW]} * \text{Annual operating hours [hrs]}$$

The Project Sponsor reports the peak demand and energy savings to EPE in the Savings Report.

Example

For a new agricultural processing plant, a high-efficiency, constant-speed motor is specified for installation. As indicated in the mechanical plans, the motor is a 200 hp, 1800 RPM enclosed motor with a nominal efficiency of 0.96.

The Standard Motor Efficiency Table lists the minimum efficiency for the baseline motor as 0.945.

Post-construction spot measurements indicate an average, one-hour, power draw of 117.9 kW.

Using Equation 3.1, the baseline demand is calculated as follows:

Baseline motor demand = 117.9 * (0.96/0.945) **=** 119.7 kW

Post-construction metering of operating hours for a one-week period show that the motor operates for 81 hours out of the 168 hours in the metering period. Using Equation 3.2, the annual operating hours of the motor is calculated as follows:

Annual operating hours = (81/168)*8760 **=** 4,224 hrs

Peak demand savings and energy savings are calculated using Equations 3.3 and 3.4, respectively, as follows:

Peak demand savings = 119.7 kW – 117.9 kW **= 1.8 kW**

Annual energy savings = 1.8 kW * 4224 hrs **= 7,603 kWh**

4 Measurement and Verification Using Stipulated Savings Factors

4.1 Overview

Stipulated savings factor measurement and verification (M&V) techniques involve establishing the efficiency of a system before and after installation by multiplying the difference by an agreed-upon, or “stipulated” factor, such as operating hours or system load. These stipulated factors represent a project’s potential to generate savings based on engineering analysis and simple verification activities.

Stipulated savings factor M&V methods are appropriate only for projects in which the following apply for the baseline and post-installation case:

- Electrical demand is constant, or varies as a function of operating scenarios—e.g., baseline damper position or installed motor speed; for each scenario, the electrical demand can be determined from spot measurements.
- Operating hours as a function of an operating schedule can be stipulated.

If the equipment involved in a project has a complex load profile and/or a complicated operating schedule, a different M&V method should be used.

Any Project Sponsor considering the use of stipulated savings factors not specified in this program should consult with EPE and get their approval prior to submitting an M&V plan.

The M&V method described here is based on Option A of the International Performance Measurement and Verification Protocol (IPMVP).

4.1.1 Data Types

Three types of data sources may be needed to estimate energy savings with an M&V plan using stipulated savings factors:

- Published data, including manufacturer-supplied performance data, operator’s logs, results from measures in similar facilities.
- Facility or equipment surveys that identify equipment type, nameplate data, counts, applications, general operating characteristics, and documented schedules from energy management systems.
- Spot/short term metering that indicates power draw for different operating characteristics.

The types of data needed to verify energy savings for a specific project will depend on its complexity and the availability of relevant stipulated data. **All stipulated factors must be clearly explained and supported by the Project Sponsor in the M&V plan.** There may be sizable differences between published equipment performance information and actual operating data. Where discrepancies exist or are believed to exist, equipment performance parameters should be measured directly.

4.2 Documenting Baseline Characteristics

Establishing the operating characteristics of the baseline equipment involves the following steps:

1. The Project Sponsor conducts a pre-construction equipment inventory/review.
2. Either EPE or its contractor performs a pre-construction inspection (if necessary).
3. The Project Sponsor develops stipulated savings factors.

4.2.1 Pre-Construction Equipment Inventory

The Project Sponsor is required to conduct an inventory of all specified equipment as part of the Final Application. The purpose of the inventory is to identify all the equipment being included in the project, and to characterize the expected operation of the equipment. For each piece of high efficiency equipment, the survey should list (as applicable) the location, manufacturer, model number, rated capacity, energy use factors (such as voltage, rated amperage, fixture wattage), nominal efficiency, load served, and any other identifiers that affect system energy consumption.

4.2.2 Pre-Construction Inspection

A pre-construction site inspection is generally not required, but in some cases—such as projects involving additions to existing facilities—this inspection may be requested at EPE's discretion.

4.2.3 Development of Stipulated Savings Factors

The Project Sponsor may use a variety of sources in the development of stipulated savings factors, including manufacturer's data, historical values, documented schedules from energy management systems, and results from measures in similar facilities. The equipment inventory is used to confirm that the stipulated factors proposed in the M&V plan are appropriate for the equipment type, application, and general operating characteristics of the project.

EPE must approve all stipulated savings factors, so all data sources, methodologies, and assumptions used in their development by the Project Sponsor must be clearly outlined in the M&V plan.

4.2.4 Compliance with Energy Standards

When using stipulated savings methods, the Project Sponsor should document the applicable minimum state and federal energy standards.

- Baseline equipment should meet *prescriptive* efficiency standard requirements for affected equipment (e.g., ASHRAE Standard 90.1-1999).

- The baseline need not comply with performance compliance methods that require the project site to meet an energy budget.
- Demand and energy savings should be calculated with the incorporation of minimum state and federal energy efficiency standards or codes into the determination of baseline energy use.

4.3 Documenting Post-Construction Characteristics

When construction is complete, the following steps are taken:

1. The Project Sponsor conducts an equipment survey.
2. Either EPE or its contractor conducts an inspection.
3. The Project Sponsor verifies stipulated savings factors using data from the installed system.

4.3.1 Post-Construction Equipment Survey

The Project Sponsor is required to conduct a post-construction equipment survey as part of the Installation Report. The purpose of this equipment survey is to document the equipment that was actually installed as part of a project. For each piece of equipment, the survey should list (as applicable) the location, manufacturer, model number, rated capacity, energy use factors (such as voltage, rated amperage, fixture wattage), nominal efficiency, load served, and any independent variables that affect system energy consumption.

4.3.2 Post-Construction Inspection

Either EPE or its contractor conducts an inspection to verify that the Project Sponsor has properly documented the installed equipment and that the stipulated savings values in the M&V plan are appropriate. After the inspection, EPE either accepts or rejects the Installation Report and the proposed stipulated savings factors based on the inspection results and project review.

4.3.3 Verification of Stipulated Savings Factors

The post-construction inspection results are used by EPE to verify that the stipulated factors proposed in the M&V plan are still appropriate for the installed equipment and the general operating characteristics. Spot- or short-term monitoring may be required to confirm their applicability to a specific project.

4.4 Calculation of Demand and Energy Savings

Once the installed equipment is verified to be operating properly and the proposed stipulated savings factors have been approved by EPE, the Project Sponsor must calculate the demand and energy savings generated by the project. The best approach for calculating the project's savings depend on the type of project and the data collected, but, in general, actual metered/measured equipment operating data should be used as much as possible.

All equations used in calculating energy savings should be included in the project's M&V plan. For example, Equation 4.1 and Equation 4.2 may be used for a project that decreases equipment electric demand but causes no change in operating hours.

Equation 4.1 Demand Savings
Demand Savings [kW] = $kW_{Baseline} - kW_{Post\text{-}installation}$

Equation 4.2 annual energy savings, stipulated hours
Annual Energy Savings [kWh] = $(kW_{Baseline} - kW_{Post\text{-}installation}]) * Hours_{Stipulated}$

Where:

$kW_{Baseline}$ = Baseline equipment demand as predicted during the utility peak, summer coincident load period.

$kW_{Post\text{-}installation}$ = Installed equipment demand as measured by short-term metering during the utility peak, summer coincident load period.

$Hours_{Stipulated}$ = Annual operating hours determined using stipulated factor.

4.5 Project-Specific M&V Issues

When stipulated factors are used to calculate energy savings, the Project Sponsor must address the following in the M&V plan:

- How accurately stipulated factors will reflect actual energy savings
- How well the stipulated factors are supported by other data sources, physical observations, or monitoring data
- How appropriate the stipulated factors are to the equipment and operating conditions involved in the project
- How the baseline energy consumption estimates incorporate minimum state and federal energy efficiency standards or codes

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5 Measurement and Verification for Generic Variable Loads

5.1 Overview

High-efficiency end-use systems that exhibit variable energy demand or operating hours may require continuous metering to measure and verify energy savings. Examples of such projects are constructions that involve:

- building automation systems
- industrial process equipment or systems
- chiller plant optimization, including chillers, cooling towers, pumps, etc.

The use of continuous metering for measurement and verification (M&V) of variable loads normally involves four steps:

1. Reviewing the pre-construction system(s). As with all M&V methods, the Project Sponsor must review plans and specifications to document relevant components (e.g., piping and ductwork diagrams, control sequences, and operating parameters).
2. Establishing a baseline model (e.g., an equation that determines energy use when key independent variables are known). All, or a representative sample, of the systems should be modeled to establish regression-based equations or curves for defining baseline system energy use as a function of appropriate variables (e.g., weather or cooling load).
3. Monitoring energy use and/or independent variables such as weather. Monitoring can be done continuously throughout a full year or for representative periods of time during each performance year.
4. Determining the savings by subtracting the post-construction energy use from the baseline energy use (as indicated in the baseline model).

The M&V method described here is based on Option B of the International Performance Measurement and Verification Protocol (IPMVP). More details on this method can be found in the IPMVP.

5.2 Documenting Baseline Characteristics

To establish the baseline characteristics of the new-construction systems, the following steps are taken:

1. The Project Sponsor conducts a pre-construction equipment inventory/review.
2. Either EPE or its contractor conducts a pre-construction inspection, if necessary.

3. The Project Sponsor develops a baseline energy consumption model.

5.2.1 Pre-Construction Equipment Survey

The Project Sponsor is required to conduct a pre-construction equipment survey, which is part of the Final Application. The equipment survey itemizes all specified equipment involved in the project. For each piece of equipment, the survey should list (as applicable) the location, manufacturer, model number, rated capacity, energy use factors (such as voltage, rated amperage, MBtu/hr, fixture wattage), nominal efficiency, load served, and any independent variables that affect system energy consumption.

5.2.2 Pre-Construction Inspection

A pre-construction site inspection is generally not required, but in some cases—such as projects involving additions to existing facilities—this inspection may be requested at EPE's discretion.

5.2.3 Baseline Model Development

The energy use of most projects is influenced by independent variables. For such projects, the Project Sponsor must develop a model (typically using regression techniques) that links independent-variable data to energy use. The Project Sponsor must include an explanation of the methodologies used for creating such a model in the Final Application for EPE's review.

Project Sponsors should use manufacturer-supplied performance data and/or other performance documentation to establish the relationship between independent variables and energy use. This relationship is known as the "Baseline System Model" and will likely take the form of an equation. Regression analysis is typically used to develop such an equation, although other mathematical methods may be approved. If regression analysis is used, it must be demonstrated that that the model is statistically valid.

The criteria for establishing statistical validity of the model are:

- The model makes intuitive sense; that is, the explanatory variables are reasonable, and the coefficients have the expected sign (positive or negative) and are within an expected range (magnitude).
- The modeled data represent the population.
- The model's form conforms to standard statistical practice and modeling techniques for the system in question.
- The number of coefficients is appropriate for the number of observations.
- The T-statistic for each term in the regression equation is equal to at least 2 (indicates with 95% confidence that the associated regression coefficient is not zero). The regression R^2 is at least 80%.
- All data entered into the model are thoroughly documented and model limits (range of independent variables for which the model is valid) are specified.

The Project Sponsor includes the data used in model development in the Final Application or Installation Report. Either EPE or its contractor makes a final determination on the validity of models and monitoring plans and may request additional documentation, analysis, or metering.

5.2.4 Compliance with Energy Standards

The baseline model must comply with all applicable federal and state energy standards and codes. If any existing equipment that will be part of the project (as may be the case in a new-construction addition to an existing building) does not meet the applicable standards, the Project Sponsor must document how the baseline model will be adjusted to account for the standards. In general, however, the M&V plan should document that the

- Baseline equipment characterization meets prescriptive efficiency standards requirements for affected equipment (e.g., ASHRAE Standard 90.1).
- Baseline need not comply with performance compliance methods that require the project site to meet an energy budget.
- Demand and energy savings are calculated with the incorporation of minimum state and federal energy efficiency standards or codes into the determination of baseline energy use.

5.3 Documenting Post-Construction Characteristics

When construction is complete, the following steps are taken:

1. The Project Sponsor conducts an equipment survey.
2. Either EPE or its contractor conducts an inspection.
3. The Project Sponsor conducts any necessary data collection.

5.3.1 Post-Construction Equipment Survey

The Project Sponsor is required to conduct a post-construction equipment survey to be submitted as part of the Installation Report. This equipment survey documents the equipment that was actually installed. For each piece of equipment, the survey should list (as applicable) the location, manufacturer, model number, rated capacity, energy use factors (such as voltage, rated amperage, MBtu/hr, wattage), nominal efficiency, load served, and any independent variables that affect system energy consumption.

5.3.2 Post-Construction Inspection

Either EPE or its contractor conducts an inspection to verify that the Project Sponsor has properly documented the installed equipment. After the inspection, EPE either accepts or rejects the Installation Report based on the inspection results and project review.

5.3.3 Post-Construction Data Collection

The Project Sponsor must monitor one or both of the following variables simultaneously:

Independent variables that affect energy use. Examples of such data are ambient temperature, control outputs, flow rate, cooling tons, and building occupancy.

System energy consumption. Energy demand (kW) of installed equipment, metered over a time period representative of the full range of system operation.

The variable(s) monitored depend on the variable(s) modeled in the Baseline System Model.

5.4 Calculation of Demand and Energy Savings

There are two approaches for calculating demand and energy savings from generic variable load projects. Both approaches require baseline modeling (as previously discussed) and post-construction metering.

The first approach requires continuous metering of demand and the independent variables used in the baseline model. Post-construction variable data are used with the baseline model to calculate baseline energy use.

The second approach involves developing a post-construction model from short-term metering of demand and continuous metering of independent variables. Continuous metering of post-construction variables are then used in the baseline and post-construction models to calculate baseline and post-construction energy use.

5.4.1 First Approach: Metering Post-Construction Energy Use and Variables

To calculate energy savings using the first approach, the Project Sponsor monitors demand and the same independent variables that were used for the System Baseline Model. The Project Sponsor then inputs the post-construction independent variable data to the System Baseline Model and compares post-construction energy use with baseline energy use. Demand and energy savings, over a single observation interval, are calculated using Equations 5.1 through 5.3.

Equation 5.1 Demand Savings
Demand Savings [kW] = $kW_{Baseline,Max} - kW_{Measured,Max}$

Equation 5.2 Energy Savings
Energy Savings_i [kWh] = $(kW_{Baseline,i} - kW_{Measured,i}) * T_i$

Equation 5.3 Energy Savings
Annual Energy Savings [kWh] = $\text{Sum of (Energy Savings)}_i$

Where:

$kW_{Baseline,Max}$ = Maximum, baseline equipment demand occurring during utility peak, summer, coincident load period.

$kW_{Measured,Max}$ = Maximum, post-construction equipment demand occurring during utility peak, summer, coincident load period.

$kW_{Baseline,i}$ = Baseline kW calculated from Baseline System Model and corresponding to same time interval, system output, weather, etc., conditions as $kW_{Measured,i}$.

$kW_{Measured,i}$ = Measured kW obtained through continuous, or representative period, post-construction metering.

T_i = Length of time interval.

5.4.2 Second Approach: Metering Post-Construction Variables

To calculate energy savings using the second approach, the Project Sponsor must first develop a Post-Construction System Model (derived from the Baseline System Model) for use as a proxy for direct post-construction energy use measurement. Then, the Project Sponsor monitors the relevant independent variables and uses that data to estimate post-construction energy use. Once the post-construction energy use is estimated, energy savings over the course of a single observation interval will be calculated using the following Equations 5.4 through 5.6.

Equation 5.4 Demand Savings
Demand Savings [kW] = $kW_{Baseline,Max} - kW_{Post\text{-}installation,Max}$

Equation 5.5 Energy Savings
$Energy\ Savings_i$ [kWh] = $(kW_{Baseline,i} - kW_{Post\text{-}installation,i}]) * T_i$

Equation 5.6 Demand Savings
Annual Energy Savings [kWh] = Sum of $(Energy\ Savings)_i$

Where:

$kW_{Baseline,Max}$ = Maximum, baseline equipment demand occurring during utility peak, summer, coincident load period.

$kW_{Post\text{-}installation,Max}$ = Maximum, post-construction equipment demand occurring during utility peak, summer, coincident load period.

$kW_{Baseline,i}$ = Baseline kW calculated from Baseline System Model and corresponding to same time interval, system output, weather, etc., conditions as $kW_{Post\text{-}installation,i}$.

$kW_{Post\text{-}installation,i}$ = Post-construction kW calculated from Post-Construction System Model and corresponding to the measured time interval measured system output, measured weather variables, etc. in the post-construction period.

T_i = Length of time interval.

For a particular observation interval, the monitored data must be applied to the Baseline System Model and to the Post-Construction System Model to determine the baseline-system energy and post-construction system energy input. The modeled-system post-construction is then subtracted from the baseline energy input value. Energy savings are determined by multiplying this difference by the length of the observation interval.

5.5 Project-Specific M&V Issues

Specific M&V issues that need to be addressed for generic variable load projects include:

- Determination of post-construction metering approach—i.e., metering of energy use or post-construction variables.
- Modeling methodology for Baseline System Model and Post-Construction Model (if used).
- Identification of appropriate variables.
- Duration of post-construction metering.

6 Measurement and Verification Using Calibrated Simulation Analysis

6.1 Overview

This section outlines the use of computer simulation analysis for measurement and verification of new construction energy savings. Computer simulation analysis should be used when the energy impacts of the energy efficiency measures are too complex[17] or too costly to analyze with traditional M&V methods. Computer-based building energy simulations are appropriate for constructions in which

- A building energy management or control system is specified
- The degree of interaction among multiple measures is either unknown or too difficult or costly to measure.
- The measures involve improvements that primarily affect building load—e.g., thermal insulation, low-emissivity windows

Conducting simulation analysis is often a time-consuming and expensive task, and the costs associated with this approach may be prohibitive in some instances. Also, building simulation software programs are not always capable of modeling every type or combination of energy efficiency measures.

The approach described here is based, in part, on Option D of the International Performance Measurement and Verification Protocol (IPMVP). More information on computer simulation analysis can be found in the IPMVP.

This approach requires that the Project Sponsor

1. Work with EPE to define a strategy for creating a calibrated building simulation model in the project-specific M&V plan.
2. Collect the required data from architectural drawings, mechanical plans, equipment schedules, and equipment submittals.
3. Adapt the data and enter them into the program's input files.
4. Run the simulation program for the "as-built" high-performance building model. The "as-built" building is the newly constructed building with all energy efficiency measures installed.

[17] Wolpert, J.S. and J. Stein, "Simulation, Monitoring, and the Design Assistance Professional," 1992 International Energy and Environment Conference.

5. Calibrate the model by comparing its output with measured data. The weather data for the model should be the actual weather occurring during the metering period. Refine the model until the program's output is within acceptable tolerances of the measured data.

6. Run the calibrated as-built model using typical weather data to normalize the results.

7. Repeat the process for the baseline building model. The baseline building model is the newly constructed building with specifications that reflect applicable minimum performance values (from ASHRAE 90.1 1999 or from the minimum state and federal energy standards, whichever are more efficient).

8. Calculate the savings by subtracting the as-built results from the baseline results. EPE reviews and verifies the savings estimates and simulation results.

These steps are described in more detail in the following sections.

6.2 Software Selection

EPE recommends that the Project Sponsor use the most current version available of the DOE-2.1E hourly building simulation program. For projects with small projected incentive payments, the Project Sponsor may use another program, provided that the program can be shown to adequately model the building, the system or equipment installations can be calibrated to a high level of accuracy, and the calibration can be documented.

6.3 Developing a Calibrated Simulation Strategy

A sound approach to measuring and verifying your savings using computer simulation analysis must include the activities listed below. The Project Sponsor and Utility Administrator should confer on the best approach to each activity.

- Employ an experienced building modeling professional. Although new simulation software packages make much of the process easier, a program's capabilities and real data requirements are not fully understood by inexperienced users. Employing an experienced modeler can save a significant amount of time.
- Define the baseline building. In general, the baseline building represents the building, as it would have been build had minimum standard equipment been installed instead of the high-efficiency equipment.
- Define the as-built building, which represents building as it was constructed, with all the installed high efficiency equipment and systems.
- Define the calibration interval. The as-built model should be calibrated using hourly, daily, or monthly data. Calibrations to hourly or daily data are preferred; these data are generally more accurate than calibrations to monthly data because there are more points to compare. If monthly billing data are used, then spot or short-term data measurements for calibrated key values may be used.

- Specify spot and short-term measurements to be taken of building systems. These measurements augment the whole-building data and enable the modeler to accurately characterize building systems. Spot and short-term measurements are valuable, but may add significant cost and time to the project.

6.4 Data Collection

The volume of data required for simulating a real building is significant. The Project Sponsor needs to collect data from the following sources:

- **As-built building plans**. The Project Sponsor should work with the building owner to gather as-built building plans.
- **Utility bills**. The Project Sponsor should collect utility bills for a *minimum* of twelve consecutive months following construction. The billing data should include monthly consumption (kWh) and peak electric demand (kW), preferably in fifteen-minute or hourly intervals (for optimal calibration). If interval data are not available, the Project Sponsor may need to arrange for the installation of metering data to collect the necessary data. Also, the Project Sponsor should determine if building systems are sub-metered, and collect these data if available.
- **Conduct on-site surveys and reviews of mechanical plans.** EPE helps the Project Sponsor establish which data must be collected. The Project Sponsor should visit the site to verify the accuracy of the mechanical plan data. EPE may accompany the Project Sponsor during this survey. Depending on the project, the Project Sponsor should collect data for
    - primary HVAC equipment (e.g. chillers and boilers): capacity, number, model and serial numbers, operation schedules
    - secondary HVAC equipment (e.g., air handling units, terminal boxes): fan sizes and types, motor sizes and efficiencies, design flow rates and static pressures, duct system types, economizer operation and control
    - HVAC controls, including the location of zones, temperature set-points, control set-points and schedules, and any special control features
    - building envelope and thermal mass: dimensions and type of interior and exterior walls, properties of windows, and building orientation and shading
    - lighting systems: number and types of lamps, with nameplate data for lamps and ballasts, lighting schedules
    - plug loads: summarize major and typical plug loads for assigning values per zone
    - occupancy: population counts, occupation schedules in different zones
    - other major energy consuming loads: type (industrial process, air compressors, water heaters, elevators), energy consumption, schedules of operation

- **Interview operators**. Building operators can provide much of the above listed information, and can also inform on any deviation in the intended operation of equipment.
- **Make spot measurements.** To determine the actual power draw of operating equipment, the Project Sponsor may find it necessary to meter on certain circuits (lighting, plug load, HVAC equipment).
- **Conduct short-term measurements**. Data-logging monitoring equipment may be set up to record system data as they vary over time. These data reveal how variable load data change weather, occupancy, daily schedules, etc. These measurements may involve lighting systems, HVAC systems, and motors. The period of measurement should be from one to several weeks.
- **Obtain weather data.** Calibrating a computer simulation of a real building for a specific year requires the use of actual weather data in the analysis. Actual weather data should be collected from a source such as National Climatic Data Center (NCDC) weather station data. The physical location of the weather station should be the closest available to the project site. These data should be translated into weather data files that are compatible with DOE-2. The project-specific M&V plan should specify which weather data sources will be used.

  Typical weather data used in the calculation of energy savings should be either Typical Meteorological Year (TMY) or TMY2 data types, obtained from the National Renewable Energy Laboratory (NREL).

6.5 Building Simulation Models

Once all necessary information is collected, the Project Sponsor inputs the data into DOE-2 code to create the as-built model. The modeler should refine the model to obtain the best representation of the as-built building. Where possible, the modeler should use measured data and real building information to verify or replace the program's default values.

6.5.1 Calibration

After the as-built model is created and debugged, the modeler should make a comparison of the energy flows and demand projected by the model to that of the utility data. All utility billing data should be used in the analysis, electric as well as heating fuels, such as natural gas. The modeler may use either monthly utility bills, or measured hourly data to calibrate the model when available.

The modeler should document the calibration process to show the results from initial runs and what changes were made to bring the model into calibration. Statistical indices are calculated during the calibration process to determine the accuracy of the model. If the model is not sufficiently calibrated, the modeler should revise the parameters of the model and recalculate the statistics.

6.5.1.1 Hourly data calibration

In hourly calibration, two statistical indices are required to declare a model calibrated: monthly mean bias error (MBE) and the coefficient of variation of the root mean squared error (C_V(RMSE))[18]. Equation 6.1 is used to calculate MBE, and Equation 6.2 is used to calculate. C_V(RMSE).

Equation 6.1 Monthly mean bias error

$$MBE(\%) = \frac{\sum_{month} (M - S)_{hr}}{\sum_{month} M_{hr}} \times 100$$

Where:

M_{hr}	=	the measured kWh for any hour during the month
S_{hr}	=	the simulated kWh for any hour during the month

Acceptable tolerance of for hourly data calibration is ± 10%.

Equation 6.2 Coefficient of variation of the root mean squared error

$$CV(RMSE_{month}) = \frac{\sqrt{\sum_{month} (M - S)_{hr}^2 * N_{hr}}}{\sum_{month} M_{hr}} * 100$$

Where:

M_{hr}	=	the measured kWh for any hour during the month
S_{hr}	=	the simulated kWh for any hour during the month
N_{hr}	=	the number of hours in the month

[18] Kreider, J. and J. Haberl, "Predicting Hourly Building Energy Usage: The Great Energy Predictor Shootout: Overview and Discussion of Results," ASHRAE Transactions Technical Paper, Vol. 100, pt. 2, June, 1994; Kreider, J. and J. Haberl, "Predicting Hourly Building Energy Usage: The Results of the 1993 Great Energy Predictor Shootout to Identify the Most Accurate Method for Making Hourly Energy Use Predictions,": ASHRAE Journal, pp. 72-81, March, 1994; Haberl, J. and S. Thamilseran, "Predicting Hourly Building Energy Use: The Great Energy Predictor Shootout II, Measuring Retrofit Savings – Overview and Discussion of Results, ASHRAE Transactions, June, 1996.

Acceptable tolerance for hourly data calibration is $\pm$ 30%

6.5.1.2 Monthly data calibration

Comparing simulated energy use to monthly utility bills is straightforward. First, the model is developed and run using weather data that correspond to the monthly utility billing periods. Next monthly simulated energy consumption data and actual measured data are plotted against each other for every month in the data set. Equation 6.3 and Equation 6.4 are used to calculate the error in the monthly and annual energy consumption, respectively.

Equation 6.3 Error in monthly energy consumption

$$ERR_{month}(\%) = \frac{(M - S)_{month}}{M_{month}} * 100$$

Where:

M_{month} = the measured kWh for the month

S_{month} = the simulated kWh for the month

Acceptable tolerance for monthly data calibration = $\pm$ 25%

Equation 6.4 Error in annual energy consumption

$$ERR_{year} = \sum_{year} ERR_{month}$$

Acceptable tolerance for monthly data calibration = $\pm$ 15%

6.5.1.3 Baseline models

After calibrated simulation of the as-built model, the baseline model can be prepared. The baseline model is usually the as-built model with the substitution of minimum energy standards for equipment and systems. This new baseline model should also be documented.

6.5.1.4 Minimum energy standards

The baseline model should comply with minimum state and federal energy standards with respect to the following:

- Baseline equipment/systems should not include devices (such as lamps and ballasts) that are not allowed under current regulations.

- Baseline equipment models should meet *prescriptive* efficiency standards for affected equipment. These requirements are found in either ASHRAE 90.1 1999 or local/federal energy codes. The applicable standard requiring the highest efficiency should be used.
- Baseline calculations *do not* have to comply with *performance compliance* methods that require the project site to meet an energy budget.

6.5.1.5 Detailed Energy Savings Calculations

Energy savings are determined from the difference between the outputs of the baseline and as-built models. Savings are determined with both models using the same conditions (weather, occupancy schedules, etc.). To calculate savings, the energy consumption projected by the as-built model is subtracted from energy consumption projected by the baseline model. Equation 6.5 is used to calculate energy savings.

Equation 6.5 Energy savings calculation

$$kWh_{saved} = kWh_{baseline} - kWh_{post}$$

Where:

$kWh_{savings}$	=	The kilowatt-hour savings realized during the year.
$kWh_{baseline}$	=	The kilowatt-hour consumption of the baseline building operating under the same conditions (weather, operation and occupancy schedules, etc.) as the as-built building.
$kWh_{As\text{-}Built}$	=	The kilowatt-hour consumption of the as-built building operating under the same conditions (weather, operation and occupancy schedules, etc.) as the baseline building.

6.6 Project-Specific M&V Issues

Project Sponsors who are using the computer simulation analysis approach must include the following in their project-specific M&V plans:

- Identification of which version of DOE-2 will be used, who will supply the program, and what, if any, pre- and post-processors will be used.
- As-built building description (age square footage, location, etc.) including a description of building systems that have been upgraded to high efficiency.
- Description of any building operation conditions (set-points, schedules, etc.) that are affected by the energy efficiency specifications.
- Documentation of compliance for the baseline model with state and federal standards.

- Documentation of the calibrated simulation strategy and project procedure, including differences in calibration parameters between the baseline and as-built cases.
- A summary of the building data to be collected and sources (e.g., site surveys, drawings).
- Identification of spot and short-term measurements to be made.
- Selection of the calibration data interval (should be hourly or monthly).
- Identification and source of weather data used (NCDC weather station or typical weather data).
- Identification of the statistical calibration tolerances and graphical techniques to be used.
- Indication of who will perform the simulation analysis and calibration.
- Specification of format for documentation.

A-F

El Paso Electric Commercial Standard Offer Program: Appendices to M&V Guidelines for Retrofit and New Construction Projects

These appendices include tables of minimum equipment efficiency standards for cooling, lighting, and motors, as well as other supplemental information about the program. This information is also available on the program Web site at **www.epelectricefficiency.com**.

A Standard Cooling Equipment Tables

A.1. Overview

This document contains reference data for estimating demand and energy savings for cooling equipment in the COMMERCIAL Standard Offer Program. The data are equipment efficiency standards or climate data that will be used to develop the baseline system models and to evaluate savings for all projects under the COMMERCIAL Standard Offer Program.

Cooling equipment installed under the program must exceed the baseline equipment efficiency standards shown in the tables. In addition, these minimum baseline efficiencies define the baseline for calculating energy savings. The guidelines in Chapter 3 in the Retrofit section (pg. R-34) and Chapter 2 in the New Construction section (pg. N-102) describe the application of these equipment efficiency standards and coefficient tables for estimating baseline demand and energy use and cooling equipment demand and energy savings.

For the following types of cooling equipment, baseline efficiency ratings are provided in Table A.1 through Table A.8 below:

- Small nitary air conditioners and heat pumps (air cooled)
- Unitary air conditioners and heat pumps (evaporatively cooled)
- Water-cooled air conditioners and heat pumps (electric)
- Packaged-terminal air conditioners and heat pumps
- Room air conditioners and heat pumps
- Large unitary air conditioners and heat pumps
- Water- and air-cooled water chilling packages
- Water chilling packages (gas absorption)

Table A.1 through Table A.8 are based on American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standards 90.1-1989 (Baseline) and 90.1-1999 (Minimum Efficiency). The tables present the minimum efficiencies of particular types of cooling equipment. The performance standard data in these tables should be used to determine the rated baseline equipment efficiencies.

The baseline efficiency for existing equipment shall be established as the 1989 standard efficiency. The baseline for equipment for which rating conditions are not provided shall be defined as the energy consumption of the actual existing equipment.Table A.1: Standard rating conditions and minimum performance for small unitary air conditioners and heat pumps, air cooled, electric, <135,000 Btu/hr (< 11.25 tons) capacity, - Except packaged terminal and room air conditioners.

Mode	Cooling Capacity	Rating Condition	Type	Baseline Performance	Minimum Performance

	Btu/hr	tons				
Cooling mode	< 65,000	< 5.42	Seasonal	Split	13 SEER	13 SEER
	< 65,000	< 5.42	Seasonal	Packaged	13 SEER	13 SEER
	≥ 65,000 & < 135,000	≥ 5.42 & < 11.25	95	Packaged and split	8.9 EER	11.2 EER†

† Deduct 0.2 from the required EERs for units with a heating section other than electric resistance heat.

$$Performance\left(\frac{kW}{ton}\right)=\frac{1}{EER}\left(\frac{Watt\cdot hr}{Btu_{out}}\right)*12{,}000\left(\frac{Btu_{out}}{ton\cdot hr}\right)*\frac{1}{1{,}000}\left(\frac{kW}{Watt}\right)=\frac{12}{EER}\left(\frac{kW}{ton}\right)$$

Table A.2: Standard rating conditions and minimum performance for unitary air conditioners and heat pumps – evaporatively cooled, electric, <135,000 Btuh (< 11.25 tons) cooling capacity.

Cooling Capacity		**Rating indoor air °F db / °F wb**	**Rating outdoor air °F db/°F wb**	**Baseline Performance Standard**	**Minimum Performance Standard**
Btuh	tons				
< 65,000	< 5.42	80/67	95/75	9.3 EER	12.1 EER
≥ 65,000 & < 135,000	≥ 5.42 & < 11.25	80/67	95/75	10.5 EER†	11.5 EER†

† Deduct 0.2 from the required EERs for units with a heating section other than electric resistance heat.

Table A.3: Standard rating conditions and minimum performance for water-cooled air conditioners and heat pumps, electric, <135,000 Btuh (< 11.25 tons) capacity.

Equipment	Cooling capacity, BTU/h	Rating Condition, air °F db / °F wb	Rating Condition, entering water °F	Baseline Performance Standard	Minimum Performance Standard
Water cooled heat pumps (Cooling Mode)	< 65,000	80/67	85	9.3 EER	-
			86	-	12.0 EER†
		75		10.2 EER	
	≥ 65,000 and <135,000	80/67	85	10.5 EER	-
			86	-	12.0 EER
Water cooled heat pumps (Heating Mode)	< 135,000	70/60	70	3.8 COP	
			68		4.2 COP
Ground water cooled heat pumps (Cooling Mode)	< 135,000	80/67	70	11.0 EER	-
			59	11.1 EER	16.2 EER
		80/67	50	11.5 EER	
Ground water cooled heat pumps (Heating Mode)	< 135,000	70/60	70	3.4 COP	-
		70/60	50	3.0 COP	3.6 COP
Water cooled unitary air conditioners	< 65,000	80/67	85	9.3 EER	-
			86	-	12.1 EER
	≥ 65,000 and <135,000	80/67	85	10.5 EER	-
			86	-	11.5 EER††

† For units with capacities less than 17,000 Btu/h, the minimum efficiency is 11.2 EER.
†† Deduct 0.2 from the required EERs for units with a heating section <u>other than</u> electric resistance heat.

Table A.4: Standard rating conditions and minimum performance for packaged terminal air conditioners and heat pumps, air-cooled, electric

Mode	Rating condition, outside air °F db	Baseline Performance Standard†	Minimum Performance Standard
Cooling	95	10-(0.16 * Cap/1000) EER	12.5-(0.213 * Cap/1000) EER
Cooling	82	12.2-(0.20 * Cap/1000) EER	-
Heating (Heat Pump)	47 db/43 wb	2.9-(0.026 * Cap/1000) COP	2.9-(0.026 * Cap/1000) COP

† Cap is the rated cooling capacity of the unit in Btu/h. If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.

Table A.5: Standard rating conditions and minimum performance for room air conditioners and room air conditioner heat pumps, electric

Category	Capacity, BTUH	Baseline performance standard (EER)	Minimum Performance Standard (EER)
Without reverse cycle and with louvered sides	< 6,000	8.0	9.7
	≥ 6,000 and <8,000	8.5	9.7
	≥ 8,000 and <14,000	9.0	9.8
	≥ 14,000 and <20,000	8.8	9.7
	≥ 20,000	8.2	8.5
Without reverse cycle and without louvered sides	< 6,000	8.0	9.0
	≥ 6,000 and <20,000	8.5	8.5
	≥ 20,000	8.2	8.5
With reverse cycle and with louvered sides	< 20,000	8.5	9.0
	≥ 20,000	8.5	8.5
With reverse cycle and without louvered sides	< 14,000	8.0	8.5
	≥ 14,000	8.0	8.0

Table A.6: Baseline and minimum performance standards for large unitary air conditioners and heat pumps, electric, ≥ 135,000 Btuh (≥ 11.25 tons) capacity.

Equipment Type	Cooling Capacity		Baseline Performance Standard		Minimum Performance Standard	
	Btuh	tons	EER	kW/ton	EER	kW/ton
Air cooled air conditioners	≥ 135,000 & <240,000	≥ 11.25 & < 20.00	8.5	1.412	11.0†	1.091
	≥ 240,000 & <760,000	≥ 20.00 & < 63.33	8.5	1.412	10.0†	1.200
	≥ 760,000	≥ 63.33	8.2	1.463	9.2†	1.304
Water or evaporatively cooled air conditioners	≥ 135,000	≥ 11.25	9.6	1.250	11.0†	1.091
Air cooled heat pumps (Cooling Mode)	≥ 135,000 & <240,000	≥ 11.25 & < 20.00	8.5†	1.412	10.6†	1.132
	≥ 240,000 & <760,000	≥ 20.00 & < 63.33	8.5†	1.412	9.5†	1.263
	≥ 760,000	≥ 63.33	8.7†	1.379	9.0†	1.333
Air cooled heat pumps (Heating Mode)	≥ 135,000 & <240,000	≥ 11.25 & < 20.00	2.9††	1.212	3.2††	1.099
	≥ 240,000 & <760,000	≥ 20.00 & < 63.33	2.9††	1.212	3.2††	1.099
	≥ 760,000	≥ 63.33	2.9††	1.212	3.1††	1.134
Air cooled condensing units	≥ 135,000	≥ 11.25	9.9	1.212	10.1	1.188
Water or evaporatively cooled condensing units	≥ 135,000	≥ 11.25	12.9	0.930	13.1	0.916

† Deduct 0.2 from the required EERs for units with a heating section other than electric resistance heat.

$$Performance\left(\frac{kW}{ton}\right) = \frac{1}{EER}\left(\frac{Watt \cdot hr}{Btu_{out}}\right) * 12{,}000\left(\frac{Btu_{out}}{ton \cdot hr}\right) * \frac{1}{1{,}000}\left(\frac{kW}{Watt}\right) = \frac{12}{EER}\left(\frac{kW}{ton}\right)$$

Table A.7: Baseline and minimum performance standards for water chilling packages, electric.

Equipment Type	Cooling Capacity (tons)	Baseline Performance Standard		Minimum Performance Standard	
		COP	kW/ton	COP	kW/ton
Water cooled, positive displacement (rotary screw, scroll)	< 150	3.80	0.926	4.45	0.790
	≥ 150 and <300	4.20	0.837	4.90	0.718
	≥ 300	4.70	0.748	5.50	0.639
Water cooled, centrifugal	< 150	3.80	0.926	5.00	0.703
	≥ 150 and <300	4.20	0.837	5.55	0.634
	≥ 300	4.70	0.748	6.10	0.577
Air cooled with condenser	< 150	2.70	1.303	2.80	1.256
	≥ 150	2.50	1.407	2.80	1.256
Air cooled without condenser	All	3.10	1.135	3.10	1.135

$$Performance\left(\frac{kW}{ton}\right)=\frac{1}{COP}\left(\frac{Btu_{in}}{Btu_{out}}\right)*12{,}000\left(\frac{Btu_{out}}{ton\cdot hr}\right)*\frac{1}{3{,}412}\left(\frac{kWh}{Btu_{in}}\right)=\frac{3.517}{COP}\left(\frac{kW}{ton}\right)$$

Table A.8: Standard rating conditions and minimum performance for water chilling packages, gas absorption

Equipment Type	Cooling Capacity	Baseline Performance Standard (COP)	Minimum Performance Standard (COP)
Air-cooled absorption, single-effect	All capacities	0.48	0.60
Water-cooled absorption, single-effect	All capacities	0.60	0.70
Absorption double effect, indirect-fired	All capacities	0.95	1.00
Absorption double effect, direct-fired	All capacities	0.95	1.00

Table A.9 of this document presents the cooling degree-days (CDD) for a weather station located in the EPE distribution service territory. Cooling degree-day data are used to normalize metered energy consumption to a typical meteorological year (TMY2). M&V Guideline 3 describes the application of weather data for estimating baseline energy use and cooling equipment energy savings.

Tables A.10 provides the coefficients necessary to complete the air-conditioning equipment *deemed savings* calculation described in Chapter 3 for Retrofit projects (pg. R-34) and Chapter 2 for New Construction projects (pg. N-102).

A.2. Tables

Table A.1: Standard rating conditions and minimum performance for small unitary air conditioners and heat pumps, air cooled, electric, <135,000 Btu/hr (< 11.25 tons) capacity, - Except packaged terminal and room air conditioners.

Mode	Cooling Capacity		Rating Condition, °F db	Type	Baseline Performance Standard[19]	Minimum Performance Standard[20]
	Btu/hr	tons				
Cooling mode	< 65,000	< 5.42	Seasonal	Split	13 SEER	13 SEER
	< 65,000	< 5.42	Seasonal	Packaged	13 SEER	13 SEER
	≥ 65,000 & < 135,000	≥ 5.42 & < 11.25	95	Packaged and split	8.9 EER	11.2 EER†

† Deduct 0.2 from the required EERs for units with a heating section other than electric resistance heat.

$$Performance\left(\frac{kW}{ton}\right)=\frac{1}{EER}\left(\frac{Watt\cdot hr}{Btu_{out}}\right)*12{,}000\left(\frac{Btu_{out}}{ton\cdot hr}\right)*\frac{1}{1{,}000}\left(\frac{kW}{Watt}\right)=\frac{12}{EER}\left(\frac{kW}{ton}\right)$$

Table A.2: Standard rating conditions and minimum performance for unitary air conditioners and heat pumps – evaporatively cooled, electric, <135,000 Btuh (< 11.25 tons) cooling capacity.

Cooling Capacity		Rating indoor air °F db / °F wb	Rating outdoor air °F db/°F wb	Baseline Performance Standard[21]	Minimum Performance Standard[22]
Btuh	tons				
< 65,000	< 5.42	80/67	95/75	9.3 EER	12.1 EER
≥ 65,000 & < 135,000	≥ 5.42 & < 11.25	80/67	95/75	10.5 EER†	11.5 EER†

† Deduct 0.2 from the required EERs for units with a heating section other than electric resistance heat.

[19] Reference: ASHRAE Standard 90.1-1989, Table 10-1 or Federal Energy Efficiency Standards
[20] Federal Energy Efficiency Standards
[21] Reference: ASHRAE Standard 90.1-1989, Table 10-2.
[22] Reference: ASHRAE Standard 90.1-1999, Table 6.2.1.A.

Table A.3: Standard rating conditions and minimum performance for water-cooled air conditioners and heat pumps, electric, <135,000 Btuh (< 11.25 tons) capacity.

Equipment	Cooling capacity, BTU/h	Rating Condition, air °F db / °F wb	Rating Condition, entering water °F	Baseline Performance Standard[23]	Minimum Performance Standard[24]
Water cooled heat pumps (Cooling Mode)	< 65,000	80/67	85	9.3 EER	-
			86	-	12.0 EER†
		75		10.2 EER	
	≥ 65,000 and <135,000	80/67	85	10.5 EER	-
			86	-	12.0 EER
Water cooled heat pumps (Heating Mode)	< 135,000	70/60	70	3.8 COP	
			68		4.2 COP
Ground water cooled heat pumps (Cooling Mode)	< 135,000	80/67	70	11.0 EER	-
			59	11.1 EER	16.2 EER
		80/67	50	11.5 EER	
Ground water cooled heat pumps (Heating Mode)	< 135,000	70/60	70	3.4 COP	-
		70/60	50	3.0 COP	3.6 COP
Water cooled unitary air conditioners	< 65,000	80/67	85 86	9.3 EER -	- 12.1 EER
	≥ 65,000 and <135,000	80/67	85 86	10.5 EER -	- 11.5 EER††

† For units with capacities less than 17,000 Btu/h, the minimum efficiency is 11.2 EER.
†† Deduct 0.2 from the required EERs for units with a heating section other than electric resistance heat.

[23] Reference: ASHRAE Standard 90.1-1989, Table 10-3 and Table 10-5.
[24] Reference: ASHRAE Standard 90.1-1999, Table 6.2.1.B.

Table A.4: Standard rating conditions and minimum performance for packaged terminal air conditioners and heat pumps, air-cooled, electric

Mode	Rating condition, outside air °F db	Baseline Performance Standard†[25]	Minimum Performance Standard[26]
Cooling	95	10-(0.16 * Cap/1000) EER	12.5-(0.213 * Cap/1000) EER
Cooling	82	12.2-(0.20 * Cap/1000) EER	-
Heating (Heat Pump)	47 db/43 wb	2.9-(0.026 * Cap/1000) COP	2.9-(0.026 * Cap/1000) COP

† Cap is the rated cooling capacity of the unit in Btu/h. If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.

Table A.5: Standard rating conditions and minimum performance for room air conditioners and room air conditioner heat pumps, electric

Category	Capacity, BTUH	Baseline performance standard (EER)[27]	Minimum Performance Standard (EER)[28]
Without reverse cycle and with louvered sides	< 6,000	8.0	9.7
	≥ 6,000 and <8,000	8.5	9.7
	≥ 8,000 and <14,000	9.0	9.8
	≥ 14,000 and <20,000	8.8	9.7
	≥ 20,000	8.2	8.5
Without reverse cycle and without louvered sides	< 6,000	8.0	9.0
	≥ 6,000 and <20,000	8.5	8.5
	≥ 20,000	8.2	8.5
With reverse cycle and with louvered sides	< 20,000	8.5	9.0
	≥ 20,000	8.5	8.5
With reverse cycle and without louvered sides	< 14,000	8.0	8.5
	≥ 14,000	8.0	8.0

[25] Reference: ASHRAE Standard 90.1-1989, Table 10-4A.
[26] Reference: ASHRAE Standard 90.1-1999, Table 6.2.1.D.
[27] Reference: ASHRAE Standard 90.1-1989, Table 10-4B.
[28] Reference: ASHRAE Standard 90.1-1999, Table 6.2.1.D.

Table A.6: Baseline and minimum performance standards for large unitary air conditioners and heat pumps, electric, ≥ 135,000 Btuh (≥ 11.25 tons) capacity.

Equipment Type	Cooling Capacity		Baseline Performance Standard[29]		Minimum Performance Standard[30]	
	Btuh	tons	EER	kW/ton	EER	kW/ton
Air cooled air conditioners	≥ 135,000 & <240,000	≥ 11.25 & < 20.00	8.5	1.412	11.0†	1.091
	≥ 240,000 & <760,000	≥ 20.00 & < 63.33	8.5	1.412	10.0†	1.200
	≥ 760,000	≥ 63.33	8.2	1.463	9.2†	1.304
Water or evaporatively cooled air conditioners	≥ 135,000	≥ 11.25	9.6	1.250	11.0†	1.091
Air cooled heat pumps (Cooling Mode)	≥ 135,000 & <240,000	≥ 11.25 & < 20.00	8.5†	1.412	10.6†	1.132
	≥ 240,000 & <760,000	≥ 20.00 & < 63.33	8.5†	1.412	9.5†	1.263
	≥ 760,000	≥ 63.33	8.7†	1.379	9.0†	1.333
Air cooled heat pumps (Heating Mode)	≥ 135,000 & <240,000	≥ 11.25 & < 20.00	2.9††	1.212	3.2††	1.099
	≥ 240,000 & <760,000	≥ 20.00 & < 63.33	2.9††	1.212	3.2††	1.099
	≥ 760,000	≥ 63.33	2.9††	1.212	3.1††	1.134
Air cooled condensing units	≥ 135,000	≥ 11.25	9.9	1.212	10.1	1.188
Water or evaporatively cooled condensing units	≥ 135,000	≥ 11.25	12.9	0.930	13.1	0.916

† Deduct 0.2 from the required EERs for units with a heating section other than electric resistance heat.

$$Performance\left(\frac{kW}{ton}\right) = \frac{1}{EER}\left(\frac{Watt \cdot hr}{Btu_{out}}\right) * 12{,}000\left(\frac{Btu_{out}}{ton \cdot hr}\right) * \frac{1}{1{,}000}\left(\frac{kW}{Watt}\right) = \frac{12}{EER}\left(\frac{kW}{ton}\right)$$

29 Reference: ASHRAE Standard 90.1-1989, Table 10-6.

30 Reference: ASHRAE Standard 90.1-1999, Table 6.2.1.A and Table 6.2.1.B or Federal Energy Efficiency Standards

Table A.7: Baseline and minimum performance standards for water chilling packages, electric.

Equipment Type	Cooling Capacity (tons)	Baseline Performance Standard[31]		Minimum Performance Standard[32]	
		COP	kW/ton	COP	kW/ton
Water cooled, positive displacement (rotary screw, scroll)	< 150	3.80	0.926	4.45	0.790
	≥ 150 and <300	4.20	0.837	4.90	0.718
	≥ 300	4.70	0.748	5.50	0.639
Water cooled, centrifugal	< 150	3.80	0.926	5.00	0.703
	≥ 150 and <300	4.20	0.837	5.55	0.634
	≥ 300	4.70	0.748	6.10	0.577
Air cooled with condenser	< 150	2.70	1.303	2.80	1.256
	≥ 150	2.50	1.407	2.80	1.256
Air cooled without condenser	All	3.10	1.135	3.10	1.135

$$Performance\left(\frac{kW}{ton}\right) = \frac{1}{COP}\left(\frac{Btu_{in}}{Btu_{out}}\right)*12{,}000\left(\frac{Btu_{out}}{ton \cdot hr}\right)*\frac{1}{3{,}412}\left(\frac{kWh}{Btu_{in}}\right) = \frac{3.517}{COP}\left(\frac{kW}{ton}\right)$$

Table A.8: Standard rating conditions and minimum performance for water chilling packages, gas absorption

Equipment Type	Cooling Capacity	Baseline Performance Standard[33] (COP)	Minimum Performance Standard[34] (COP)
Air-cooled absorption, single-effect	All capacities	0.48	0.60
Water-cooled absorption, single-effect	All capacities	0.60	0.70
Absorption double effect, indirect-fired	All capacities	0.95	1.00
Absorption double effect, direct-fired	All capacities	0.95	1.00

Table A.9: TMY2 Cooling Degree Days (base 65) for the EPE service territory

Weather Station	CDD_{65} (^{o}F day)
El Paso	**2,094**

[31] Reference: ASHRAE Standard 90.1-1989, Table 10-7.
[32] Reference: ASHRAE Standard 90.1-1999, Table 6.2.1.C.
[33] Reference: ASHRAE Standard 90.1-1999, Table 6.2.1.C.
[34] Reference: ASHRAE Standard 90.1-1999, Table 6.2.1.C.

Table A.10: Deemed savings coefficients for the El Paso (Weather Zone 2) climate for various building types and equipment types.

Building Type	Demand Coefficient			Energy Coefficient		
	Air Cooled Chiller	Water Cooled Chiller	DX Air Cooled	Air Cooled Chiller	Water Cooled Chiller	DX Air Cooled
College	0.89	0.81	0.91	1,587	1,761	1,955
Convenience			0.92			3,831
Fast Food			0.92			3,106
Grocery		0.87	0.92		2,708	2,815
Hospital	1.15	0.83		2,453	2,733	
Hotel	0.89	0.84	0.92	1,633	1,698	2,137
Motel			0.92			2,211
Nursing Home	0.90	0.82	0.92	1,744	1,854	2,218
Large Office	0.88	0.80	0.92	2,232	2,406	2,493
Small Office	0.90	0.80	0.92	1,598	1,649	1,970
Public Assembly	0.90	0.84	0.92	2,005	2,116	2,385
Restaurant			0.92			2,405
Religious Worship	0.88	0.83	0.90	1,355	1,396	1,946
Retail	0.90	0.83	0.92	1,770	1,828	2,225
School	0.88	0.81	0.91	1,136	1,273	1,569
Service			0.92			2,262
Warehouse	0.90	0.86	0.92	1,378	1,435	2,110

B Table of Standard Motor Efficiencies

B.1 Overview

This document contains reference data for estimating demand and energy savings in COMMERCIAL Standard Offer Program for energy efficient motors and related measures. For motors installed under the program, the equipment must exceed these minimum efficiency standards. In addition, the minimum efficiencies define the baseline for calculating demand and energy savings. M&V Guideline 4 for motor measures describes the application of these equipment efficiency standards for estimating baseline demand and energy use and measure demand and energy savings.

B.2 Table

The efficiencies of permanently wired, poly-phase motors that are at least one horsepower in size and that are used for fan, pumping, and conveyance applications are defined in Table B.1. Table B.1 is based on ASHRAE Standard 90.1m-1995. Note, however, that the following motors are exempt from these requirements:

- Motors in appliances.
- Refrigeration compressor motors.
- Multi-speed motors.
- Motors that are used as components of cooling equipment where the motors are part of the efficiency ratings listed in the Standard Cooling Equipment Tables.

The efficiency values given in should be used to determine the equipment baseline. Equipment installed under the COMMERCIAL Standard Offer Program must be more efficient than the standards shown in order to be eligible for incentives.

Table B.1: Minimum nominal full-load motor efficiency for single speed poly-phase motors

Motor	Horsepower	2-Pole	4-Pole	6-Pole	8-Pole
Open	1.0	--	81.5	78.5	72.0
	1.5	81.5	82.5	82.5	74.0
	2.0	82.5	82.5	84.0	84.0
	3.0	82.5	85.5	85.5	85.5
	5.0	84.0	86.5	86.5	86.0
	7.5	86.5	87.5	87.5	87.5
	10.0	87.5	88.5	89.5	88.5
	15.0	88.5	90.2	89.5	88.5
	20.0	89.5	90.2	90.2	89.5
	25.0	90.2	91.0	91.0	89.5
	30.0	90.2	91.7	91.7	90.2
	40.0	91.0	92.4	92.4	90.2
	50.0	91.7	92.4	92.4	91.0
	60.0	92.4	93.0	93.0	91.7
	75.0	92.4	93.6	93.0	93.0
	100.0	92.4	93.6	93.6	93.0
	125.0	93.0	94.1	93.6	93.0
	150.0	93.0	94.5	94.1	93.0
	200.0	94.1	94.5	94.1	93.0
Enclosed	1.0	74.0	81.5	78.5	72.0
	1.5	81.5	82.5	84.0	75.5
	2.0	82.5	82.5	85.5	81.5
	3.0	84.0	86.5	86.5	82.5
	5.0	86.5	86.5	86.5	84.0
	7.5	87.5	88.5	88.5	84.0
	10.0	88.5	88.5	88.5	87.5
	15.0	89.5	90.2	89.5	87.5
	20.0	89.5	90.2	89.5	88.5
	25.0	90.2	91.7	91.0	88.5
	30.0	90.2	91.7	91.0	90.2
	40.0	91.0	92.4	92.4	90.2
	50.0	91.7	92.4	92.4	91.0
	60.0	92.4	93.0	93.0	91.0
	75.0	92.4	93.6	93.0	92.4
	100.0	93.0	94.1	93.6	92.4
	125.0	94.1	94.1	93.6	93.0
	150.0	94.1	94.5	94.5	93.0
	200.0	94.5	94.5	94.5	93.6

C Guide to Table of Standard Fixture Wattages

C.1 Overview

The Table of Standard Fixture Wattages contains reference data for estimating demand and energy savings in the COMMERCIAL Standard Offer Program for lighting measures. The Table assigns identification codes and demand values (watts) to common fixture types (fluorescent, incandescent, HID, LED, etc.) used in commercial applications. The Table wattage values for each fixture type are averages of various manufacturers' laboratory tests performed to ANSI test standards. By using standardized demand values for each fixture type, the Table simplifies the accounting procedures for lighting equipment retrofits.

EPE posts updated versions of the Table on the program Web site at www.epelectricefficiency.com as new fixtures are added. Project Sponsors should make sure that they are working with the most recent version of the Table as they prepare *Lighting Equipment Survey* forms. Refer to Chapter 9 (Final Application) of the Project Sponsor's Manual for further explanation of the Lighting Equipment Survey.

If a project uses a fixture type not listed in the Table, the Project Sponsor should request that EPE add a new fixture code. The request should include all information required to uniquely identify the fixture type and to fix its demand. If possible, the request should be supported by manufacturer's ANSI test data.

The *Lighting Equipment Survey Form* is linked to a copy of the Standard Wattage Table and looks up wattage values for fixture codes automatically. For this reason, Project Sponsors should use only the identification codes included in the Table.

C.2 Table

The Table is subdivided into fixture types such as linear fluorescent, compact fluorescent, mercury vapor, etc, with each subdivision sorted by fixture code. Each record, or row, in the Table contains a fixture code, which serves as a unique identifier. Each record also includes a description of the fixture, the number of lamps, the number of ballasts if applicable, and the fixture wattage. A legend explains the rules behind the fixture codes.

The US Energy Policy Act of 1992 (EPACT) sets energy efficiency standards that preclude certain lamps and ballasts from being manufactured or imported into the US. Under the COMMERCIAL Standard Offer Program 2008, all lighting equipment, including existing or baseline equipment, must be EPACT compliant. As a result, certain lamp/ballast combinations, which are non-EPACT compliant, are assigned EPACT demand values. Thus, a 4-foot fixture with 40-watt T-12 lamps and a standard magnetic ballast has the same demand value as a like fixture equipped with 34-watt T-12 lamps and an energy efficient magnetic ballast.

The fixture codes and the demand values listed in the watt/fixture column in the Table of Standard Fixture Wattages must be used in calculating energy and demand savings for any lighting efficiency project in the COMMERCIAL Standard Offer Program.

D M&V Sampling Guidelines

D.1 Overview

This appendix provides guidelines for defining a sample of equipment for measurement and verification purposes. In sampling, a large number of similar pieces of equipment affected by the same energy-efficiency measure can be grouped into usage groups from which samples are selected. These sampling guidelines are designed to provide assistance in determining the number of sample points that should be monitored in order to meet the program precision requirements and provide a reliable estimate of parameters such as annual energy savings or hours of operation. If alternative approaches are proposed, they must be approved by EPE and based on sound statistical principles.

D.2 Steps in Calculating Sample Size

The number of pieces of equipment requiring monitoring can be calculated according to the following steps:

1. Compile Measurement Information

Compile the following information for the equipment affected by the measures. This step is normally undertaken during the preparation of the Final Application.

- *Number of Fixtures/Equipment.* Identify and document the fixtures/equipment that are affected by the installation of measures in a survey that includes nameplate data, quantity of equipment, and location information.
- *Projected Hours of Operation*. Project the average hours of operation of the equipment. It should be based on the experience of the building operator, on the operation of the affected equipment or even some preliminary monitoring.

2. Designate usage group

Next, provide a brief description of the functional use of the space being audited. Functional uses typically encountered in lighting for Commercial facilities are provided in Table 2.3 found in Chapter 2 of the Retrofit section (pg. R-20) of this manual. Usage groups for non-lighting measures are dependent on type of application. Sources of information on operating characteristics, other than monitoring, used in defining usage groups include: (a) operating schedules that provide information on energy consumption or hours of operation; and (b) type of application or location that provides information on how and when equipment (e.g., fixtures or motors) are operated. In some instances, area type alone may be insufficient to designate usage groups. Usage groups may need to be further subdivided if an area type is inherently variable in nature due to different characteristics of their occupants. For example, some laboratories may have longer operating hours than others and should be divided into different usage groups (e.g., computer laboratory lighting operates for 8 hours per day while agriculture laboratories operate 4 hours per day).

3. Calculate sample sizes

Once the equipment has been divided into usage groups, the total sample size needed for these groupings can be calculated. This approach produces a sample (with a coefficient of variation of 0.5) expected to estimate the average hours of operation with sufficient accuracy. The following table shows the number of samples required in a usage group.

Table D.1: Sample Size based on Usage Group Sampling

Usage Group Population	Sample Size 80/20	Sample Size 80/20, plus 10%
4	3	4
5	4	5
12	6	7
16	7	8
20	7	8
25	8	9
30	8	9
35	8	9
40	9	10
45	9	10
60	9	10
65	9	10
70	9	10
80	10	11
90	10	11
100	10	11
125	10	11
150	10	11
175	10	11
200	10	11
300	10	11
400	11	13
500	11	13

D.3 Over-sampling

The initial sample size should be increased to compensate for potential reductions in the final usable sample due to equipment failure or loss. Suggested guidelines are that the sample size be increased by 10 percent.

E Glossary

The following are definitions to commonly used terms in the EPE COMMERCIAL Standard Offer Program:

- A -

Affiliate: For purposes of the EPE Commercial Standard Offer Program, an Affiliate is:

(A) a person who directly or indirectly owns or holds at least 5.0% of the voting securities of an energy efficiency service provider;

(B) a person in a chain of successive ownership of at least 5.0% of the voting securities of an energy efficiency service provider;

(C) a corporation that has at least 5.0% of its voting securities owned or controlled, directly or indirectly, by an energy efficiency service provider;

(D) a corporation that has at least 5.0% of its voting securities owned or controlled, directly or indirectly, by:

- (i) a person who directly or indirectly owns or controls at least 5.0% of the voting securities of an energy efficiency service provider; or
- (ii) a person in a chain of successive ownership of at least 5.0% of the voting securities of an energy efficiency service provider; or

(E) a person who is an officer or director of an energy efficiency service provider or of a corporation in a chain of successive ownership of at least 5.0% of the voting securities of an energy efficiency service provider;

(F) a person who actually exercises substantial influence or control over the policies and actions of an energy efficiency service provider;

(G) a person over which the energy efficiency service provider exercises the control described in subparagraph (F) of this paragraph;

(H) a person who exercises common control over an energy efficiency service provider, where "exercising common control over an energy efficiency service provider" means having the power, either directly or indirectly, to direct or cause the direction of the management or policies of an energy efficiency service provider, without regard to whether that power is established through ownership or voting of securities or any other direct or indirect means; or

(I) a person who, together with one or more persons with whom the person is related by ownership, marriage or blood relationship, or by action in concert, actually exercises substantial influence over the policies and actions of an energy efficiency service provider even though neither person may qualify as an affiliate individually.

- B -

Baseline: For purposes of determining estimated and measured energy savings under the SOP, the baseline is generally defined as the energy consumed by equipment with efficiency levels that meet the applicable current federal standards and reflects current market conditions. In certain limited circumstances, the baseline may be determined by the equipment or conditions currently in place. This is likely to occur only when federal energy efficiency standards do not apply, or when the existing equipment can be shown by the Project Sponsor to have a remaining service life of at least ten years. For determining estimated and measured savings for building shell improvements, the baseline is generally determined by the building's current condition, e.g., existing insulation R-values, air infiltration rates, etc.

Budget Reservation: The amount of incentive funds EPE sets aside during the project implementation phase for a given Project Sponsor who has submitted a successful application prior to EPE's complete commitment of funds through Budget Reservations to other Project Sponsors.

- C -

Contracted Capacity Savings: As defined in an SOP Agreement, the amount by which a project is expected to reduce peak demand consumption (measured in kW) at the host customer's site(s).

Contracted Energy Savings: As defined in an SOP Agreement, the amount by which a project is expected to reduce energy consumption (measured in kWh) at the host customer's site(s).

- D -

Deemed Savings: A pre-determined, validated estimate of energy and peak demand savings attributable to an energy efficiency measure in a particular type of application that a utility may use instead of energy and peak demand savings determined through measurement and verification activities.

Demand Savings: The maximum average load reduction occurring during any one-hour period between 1 PM and 7 PM MDT weekdays, from May 1 through September 30 (holidays excluded). The demand savings are measured against a predetermined baseline for deemed savings measures.

- E -

Energy-Efficiency Measures (EEM): Equipment, materials, and practices that, when installed and used at a customer site, result in a measurable and verifiable reduction in either purchased electric energy consumption, measured in kilowatt-hours (kWh), or peak demand, measured in kWs, or both.

Energy Efficiency Project: An energy efficiency measure or combination of measures installed under a standard offer contract or a market transformation contract that results in both a reduction in customers' electric energy consumption and peak demand, and energy costs.

Energy Efficiency Service Provider: A person who installs energy efficiency measures or performs other energy efficiency services. An energy efficiency service provider may be a retail electric provider or a customer, if the person has executed a SOP Agreement.

Energy Savings: A quantifiable reduction in a customer's consumption of energy, or the amount by which energy consumption is reduced as a result of the installation of qualifying energy-efficient equipment. Energy savings are determined by comparing the efficiency of the installed equipment to that of new standard-efficiency equipment—*not* to that of the customer's existing equipment (except in cases where no standards currently exist).

Existing Equipment: The equipment that is installed at the host customer's site prior to the customer's participation in the SOP Program.

- H -

Host Customer or Customer: A residential, Commercial distribution customer of EPE that owns or leases facilities at a Project Site or Sites and that has entered into a Host Customer Agreement with Project Sponsor, or is a customer acting as its own Project Sponsor, for the installation of Measures as a part of Project. "Host Customer" excludes all Project Sites that are new construction or major rehabilitation projects.

- I -

Incentive Payment: Payments made to an Energy Efficiency Service Provider based on the level of approved demand and energy savings (expressed as kW and kWh). Incentive rates are based on Commission approved avoided costs and incentive caps.

Installation Payment: The first of two incentive payments made to a Project Sponsor. The implementation payment is for 40% of the total estimated incentive amount as specified in the SOP Agreement. A Project Sponsor may submit an invoice for this payment following EPE's approval of the Project Sponsor's Installation Report.

Inspection: Onsite examination of a project to verify that a measure has been installed and is capable of performing its intended function.

- M -

Measurement and Verification Plan: The Project Sponsor's specific plan for verifying measured savings estimates. The measurement and verification (M&V) plan should be consistent with the International Performance Measurement and Verification Protocol.

Measured Capacity Savings: The maximum average load reduction occurring during any one-hour period between 1 PM and 7 PM MDT weekdays, from May 1 through September

30 (holidays excluded), as determined in accordance with the Project Sponsor's Measurement and Verification Plan.

Measured Energy Savings: The Energy Savings derived during a single year, from the Measures installed at the Project Site as determined in accordance with Project Sponsor's Measurement and Verification Plan.

- P -

Peak Demand Savings: For purposes of the EPE Standard Offer Program, Peak Demand Savings is the maximum average load reduction occurring during any one-hour period between 1 PM and 7 PM MDT weekdays, from May 1 through September 30 (holidays excluded).

Peak Period: For the purposes of this program, the peak period is defined as the hours from 1 PM to 7 PM MDT weekdays, from May 1 through September 30 (holidays excluded).

Performance Period: The period following the approval of a Project Sponsor's Installation Report, during which measurement and verification are to take place. Peak demand and energy savings measured over this period form the basis of the performance payment made to the Project Sponsor at the end of the year.

Performance Payment: The second of two incentive payments made to a Project Sponsor under the terms of an SOP Agreement. The performance payment is based on the one-year measured energy savings documented in EPE's M&V Report and may be up to 60% of the total estimated incentive included in the SOP Agreement.

Post-Installation Inspection: An inspection of a project site or sites conducted by EPE after a Project Sponsor has submitted a monthly invoice. The purpose of the inspection is to verify that the energy-efficiency equipment specified in the SOP Agreement has been installed properly and is capable of performing its intended function. EPE's approval of the invoice is contingent upon the results of the post-installation inspection.

Project: All the energy-efficient measures and any associated equipment and/or improvements that are installed, maintained and/or operated by the Project Sponsor to achieve the energy savings claimed for the project.

Project Application: A set of standard forms submitted by an organization wanting to participate in the SOP Program as a Project Sponsor. On the Project Application, the Project Sponsor provides information about itself, the site at which the proposed project will be installed, and a general description of the proposed project.

Project Sponsor: Any organization, group, or individual who contracts with EPE to provide energy savings under the SOP Program.

Prudent Electrical Practices: Those practices, methods, standards, and equipment commonly used in prudent electrical engineering and operations to operate electrical equipment lawfully and with safety, dependability, and efficiency and in accordance with the National Electrical Safety Code, the National Electrical Code, and any other applicable federal, state and local codes. In the event of a conflict, the applicable federal, state, or local code shall govern.

- R -

Renewable Demand Side Management (DSM) Technologies: Equipment that uses a renewable energy resource that, when installed at a customer site, reduces the customer's net purchases of energy (kWh), electrical demand (kW), or both.

- S -

SOP Agreement: A contract entered into by the Project Sponsor and EPE following the approval of the Project Sponsor's Final Application and EPE's acceptance of a project-specific measurement and verification (M&V) plan. The SOP Agreement specifies the energy-efficiency measures to be installed, the expected energy savings, the expected total incentive payment, and the agreed-upon M&V approach.

F

Sample M&V Plan

Project Summary

An owner of a 250,000 square foot office complex is participating in EPE's Commercial Standard Offer Program. A central chilled water plant cools the facility with a 15-year-old 700-ton centrifugal chiller. The owner of the building is planning to replace the older chiller with a new, high efficiency unit. The new unit under consideration is rated with an ARI nominal COP of 7.5 (0.469 kW/Ton). The baseline efficiency standard for water-cooled electric chillers is taken from Appendix A, Table A.3 of the *Standard Cooling Equipment Tables*. For a 700-ton water-cooled chiller, the baseline efficiency is 6.1 COP, which is equivalent to 0.577 kW/ton (and the unit qualifies for the program by having a higher efficiency than the required minimum).

Assumptions

This M&V plan is written with the following assumptions:

1. The office building is not planning any major projects that would significantly alter the chiller load or schedule, such as building additions, significant changes in building occupancy, or significant changes in building schedule.
2. The chiller operating schedule will not change because of this project.

Based on the assumptions and the fact that the new chiller is similar to the existing one (similar size, water-cooled, no VFD, etc.), the only characteristic needed to estimate the demand and energy savings is the full load efficiency of each chiller.

Project Activities

The proposed method for conducting the M&V is found in Chapter 3 (pg. R-32) of this manual that deals with Cooling Equipment retrofit projects. Since the simplified guidelines are being used, pre-installation monitoring is not required. The project does require pre-installation and post-installation inspections, post-installation monitoring of chiller demand (kW for at least one hour at peak operating conditions), post-installation monitoring of chiller consumption (kWh for the entire year), an Installation Report, and a Savings Report. The Project Sponsor shall be responsible for all M&V activities and production of reports.

Inspections

EPE shall perform a pre-installation inspection to validate assumptions used in the savings calculations, and verify the existing chiller efficiency. The best source of information for the existing efficiency is the ARI certification, which accompanies the existing chiller. A post-installation inspection will be performed to verify that the chiller was installed and is operating as proposed in the approved Final Application.

Post-Installation Monitoring

Post-installation monitoring of chiller electrical consumption shall be conducted for the entire M&V period. This monitoring will be accomplished using an ACME Inc, self contained, three-phase, true RMS kW logger. The logger collects time stamped data at 15-minute intervals. The logger will be downloaded monthly and the data validated and stored. In the event that there is a significant gap in the data due to a logger failure, the process to replace the missing data with interpolated or averaged data will be clearly documented. The 15-minute time stamped data will be used to satisfy all post-installation monitoring requirements.

Reports

After the chiller is installed and commissioned, an Installation Report will be produced documenting that the equipment specified in the FA was installed and is functioning as expected. A Savings Report, following the guidelines and forms provided in the procedures manual, will be generated and submitted upon completion of the data collection activities. Savings estimates will be provided in spreadsheet form, following the template provided in Table 2, below. In addition to the reports, all monitoring data will be submitted in electronic format for review by EPE.

Metering Plan

The electrical demand of the proposed (new) chiller will be monitored to support the required M&V activities. This three-phase load will be monitored using an ACME true RMS kW meter. Current Transducers will be placed on Breakers 1, 3 and 5 of switchgear SG-1. These breakers are the A, B, and C phases of the 460-volt service that supplies the chiller. No other devices draw power from these breakers.

The ACME meter will record electrical consumption at 15 Minute intervals for the duration of the monitoring period. This logger is capable of storing 41 days of 15-minute data using a fifteen minute interval. Data will be downloaded and stored on the first working day of each month to ensure that the logger does not run out of memory.

Accuracy Requirements

The ACME logger will be calibrated at the time of installation and then checked for calibration every 6 months. This will be accomplished using a Powersite true RMS meter calibrated at the factory to ±2 percent of reading.

Data Gathering and Quality Control

The data will be collected using quality control procedures for checking reasonableness. Any and all missing intervals will be replaced either by interpolation or use of average values. EPE will be notified of any data substitution because of missing data, and the method employed to substitute the data.

Calculations and Adjustments

The calculations described below will be performed for the Savings Report and will form the basis of incentive payments. The nominal efficiencies of the chillers are provided again in Table F.1 below.

Table F.1: Proposed and Baseline Chiller Statistics

Chiller	Efficiency (COP)	Full-Load kW
Baseline	6.1	404
Proposed	7.5	328

Using the post-installation data described above and the information in Table F.1, the savings will be calculated using Equations F.1 and F.2.

Equation F.1: Calculation of Energy Savings

$$\text{Energy Savings[kWh]} = \text{Post Installation Metering [kWh]} \bullet \left\{ \left[\frac{\text{COP of new chiller}}{\text{Baseline COP}} \right] - 1 \right\}$$

Equation F.2: Calculation of Peak Demand Savings

$$\text{Demand Savings[kW]} = \text{Max Demand Measured [kW]} \bullet \left\{ \left[\frac{\text{COP of new chiller}}{\text{Baseline COP}} \right] - 1 \right\}$$

The ratio of new to existing chiller is computed as 7.5 divided by 6.1 to yield 1.23. Table F.2 below provides a template to illustrate how monthly savings calculations will be estimated when actual M&V data are available.

Table F.2: Template for Computing Savings

Time of Day	Measured kW for peak day in June (hourly average)	Peak savings (kW)	Average demand profile in June (kW)	Days of Operation for June	Energy Consumption (kWh)	Energy Savings for June (kWh)
0:00	127.0	29.1	82.6	23	1899	436
1:00	142.4	32.7	92.6	23	2129	489
2:00	134.8	30.9	87.6	23	2015	462
3:00	127.0	29.1	82.6	23	1899	436
4:00	134.8	30.9	87.6	23	2015	462
5:00	127.0	29.1	95.3	23	2191	503
6:00	142.4	32.7	106.8	23	2456	564
7:00	173.2	39.7	129.9	23	2988	686
8:00	269.6	61.9	202.2	23	4651	1067
9:00	288.8	66.3	216.6	23	4982	1143
10:00	319.6	73.3	271.7	23	6248	1434
11:00	346.6	79.5	294.6	23	6776	1555
12:00	354.2	81.3	301.1	23	6925	1589
13:00	358.0	82.2	304.3	23	6999	1606
14:00	362.0	83.1	271.5	23	6245	1433
15:00	365.8	84.0	274.4	23	6310	1448
16:00	365.8	84.0	274.4	23	6310	1448
17:00	346.6	79.5	260.0	23	5979	1372
18:00	327.2	75.1	245.4	23	5644	1295
19:00	308.0	70.7	200.2	23	4605	1057
20:00	192.6	44.2	125.2	23	2879	661
21:00	127.0	29.1	82.6	23	1899	436
22:00	142.4	32.7	92.6	23	2129	489
23:00	115.6	26.5	75.1	23	1728	397
Total Savings:		84.0				22,468

The illustrative load data represents chiller consumption in the month of June. Energy savings (kWh) will be estimated in each month by multiplying the average hourly kWh with the number of days in the month and then applying equation F.1. The energy savings for each month will then be aggregated into an annual savings estimate. The peak data shall be used in equation F.2 to estimate the peak demand savings (kW).