IV

C&I Standard Offer Program Measurement and Verification Guidelines For New Construction Projects

This section includes detailed information about the measurement and verification (M&V) requirements of the Commercial and Industrial 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

Overview

In the Commercial and Industrial (C&I) Standard Offer Program (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 the Utility Administrator and adhere to the *2001 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 the Utility Administrator 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 2001 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 the Utility Administrator 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 the Utility Administrator 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 the Utility Administrator 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

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 the Utility Administrator 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 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 are a function of the project site characteristics and the savings potential.

For lighting efficiency measures installed in electrically cooled spaces, 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.

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. The Utility Administrator or its contractor will conduct a post-installation inspection to verify the installation of the specified equipment.

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).

Pre-installation M&V Activities

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 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 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[1]:

- 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.

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

- 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.
- 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.

Post-installation M&V Activities

Post-installation equipment survey

The 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 Sponsor enters all fixtures into the Survey form, the form calculates the building's installed interior lighting load.

Post-installation inspection

The Utility Administrator or its contractor will conduct a post-installation inspection to verify that the measures were installed as reported. In most cases, the Utility Administrator 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%, the Utility Administrator will inform the Sponsor that the submitted lighting survey must be corrected and resubmitted, citing the major cause of the errors found.

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 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[2]

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			

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.

[2] 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[3]	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.

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 the Utility Administrator'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 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.

[3] At the time this manual was published, the Texas Public Utilities Commission had not approved the stipulated operating hours and coincidence factors for Colleges and Universities, Multi-Family Housing Common Areas, or Parking Structures. Please check with The Utility Administrator before using these deemed savings values.

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

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]

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	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.

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 Sponsor should conduct all meter installation, retrieval and data analysis.

Pre-installation M&V Activities

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 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. Once the 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[4]:

- 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.
- 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.

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

- 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.

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.

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

Post-installation M&V Activities

Post-installation equipment survey

The 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.

Post-installation inspection

The Utility Administrator or its contractor will conduct a post-installation inspection to verify that the specified equipment was installed as reported. In most cases, the Utility Administrator 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%, the Utility Administrator will inform the Sponsor that the submitted lighting survey table must be corrected and resubmitted, citing the major cause of the errors found.

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 FA review and approval, the Utility Administrator 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 peak-demand period.

The required sample sizes for each usage group are noted in Table 1.. Note that, because light loggers sometimes fail, over-sampling is strongly recommended. Light loggers should be tested prior to installation to verify that the light loggers are functioning properly.

Table 1.4: Monitoring sample sizes*

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

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

Calculation of average operating hours

The 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 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 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 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.

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". Interactive HVAC demand and energy savings may be calculated only for lighting installed in conditioned spaces. Lighting in unconditioned spaces, such as parking garages, is not eligible for interactive HVAC savings payments.

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:

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

Peak demand savings

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

Energy savings

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

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

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".

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 Utility Name 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 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 schdule 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 convience 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.

Pre-Installation M&V Activities

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.

Post-Installation M&V Activities

Post-installation Equipment Survey

Once the construction project is complete, the 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 Sponsor must submit manufacturer's documentation of the rated efficiency of all 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.

Post-installation Inspection

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

Deemed Savings Calculations

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

Equation 2.1: 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 2.2: Calculation of energy savings for cooling equipment

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

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.
η_{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.
$\eta_{\text{post-installation}}$	=	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[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 ($\eta_{\text{post-installation}}$).

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.

Example

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

Step 1 The Sponsor finds the appropriate baseline efficiency 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 sponsor finds that η_{baseline} = 1.30 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 sponsor finds that $\eta_{\text{post-installation}}$ = 1.20 kW/Ton.

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

Step 4 The 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 Brownsville is 0.84, so $a = b$ = 0.84. The energy coefficient for a retail building with a DX air-cooled unit in Brownsville is 2,917, so $c = d$ = 2,917.

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

$$kW_{savings} = 150 * (0.84 * 1.30 - 0.84 * 1.20) = 12.6\ \text{kW}$$

$$kWh_{savings} = 150 * (2{,}917 * 1.30 - 2{,}917 * 1.20) = 43{,}755\ \text{kWh}$$

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

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.

Pre-Construction M&V Activities

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

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 the Utility Administrator's discretion.

Post-Installation M&V Activities

Equipment Survey

After construction is complete, the Project Sponsor provides a post-construction equipment inventory to the Utility Administrator 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.

Site Inspection

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

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.

Calculation of Demand and Energy Savings

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 NCDC station nearest the site. The value is determined by the Utility Administrator based on the metering period start and stop dates.

Example

For a Houston 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 the Utility Administrator'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 **Houston** station. The cooling degree day data for the station are **2810 °F** day for TMY2 and **2675 °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:

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

$$\Delta \mathrm{kWh} = 697{,}374 * \left\{ \left[\frac{6.6}{6.1} \right] - 1 \right\} * \left(\frac{2810}{2675} \right)$$

The energy savings equal **60,047 kWh**.

3 Simplified M&V Guidelines for Constant Load Motor Measures

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.

Pre-Construction Activities

Equipment Survey

The Project Sponsor provides an inventory of the specified equipment to the Utility Administrator 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 the Utility Administrator's discretion.

Post-Construction Activities

Equipment Survey

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

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

Site Inspection

After the Utility Administrator receives a Project Sponsor's Installation Report, either the Utility Administrator 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. The Utility Administrator will require the Project Sponsor to make any necessary corrections to the Installation Report based on the results of the inspection.

Calculation of Motor Operating Hours

After the Utility Administrator 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				
Annual operating hours [hrs/yr]	=	$\frac{\text{Motor on-time during metering period (hrs)}}{\text{Length of metering period (hrs)}}$	*	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, the Utility Administrator 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				
Peak demand savings [kW]	=	Baseline motor demand [kW]	–	Spot-measured motor demand [kW]

Equation 3.4 Energy Savings				
Energy savings [kWh]	=	Peak demand savings [kW]	*	Annual operating hours [hrs]

The Project Sponsor reports the peak demand and energy savings to the Utility Administrator 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

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

The M&V method described here is based on Option A of the 2001 International Performance Measurement and Verification Protocol (IPMVP).

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 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.

Documenting Baseline Characteristics

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

- The Sponsor conducts a pre-construction equipment inventory/review.
- Either the Utility Administrator or its contractor performs a pre-construction inspection (if necessary).
- The Sponsor develops stipulated savings factors.

Pre-Construction Equipment Inventory

The 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.

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 the Utility Administrator's discretion.

Development of Stipulated Savings Factors

The 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.

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

Compliance with Energy Standards

When using stipulated savings methods, the 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).

- 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.

Documenting Post-Construction Characteristics

When construction is complete, the following steps are taken:

- The Sponsor conducts an equipment survey.
- Either the Utility Administrator or its contractor conducts an inspection.
- The Sponsor verifies stipulated savings factors using data from the installed system.

Post-Construction Equipment Survey

The 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.

Post-Construction Inspection

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

Verification of Stipulated Savings Factors

The post-construction inspection results are used by the Utility Administrator 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.

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 the Utility Administrator, the 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.

Project-Specific M&V Issues

When stipulated factors are used to calculate energy savings, the 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

5 Measurement and Verification for Generic Variable Loads

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 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 2001 International Performance Measurement and Verification Protocol (IPMVP). More details on this method can be found in the IPMVP.

Documenting Baseline Characteristics

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

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

3. The Sponsor develops a baseline energy consumption model.

Pre-Construction Equipment Survey

The 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.

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 the Utility Administrator's discretion.

Baseline Model Development

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

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

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 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.

Documenting Post-Construction Characteristics

When construction is complete, the following steps are taken:

1. The Sponsor conducts an equipment survey.
2. Either the Utility Administrator or its contractor conducts an inspection.
3. The Sponsor conducts any necessary data collection.

Post-Construction Equipment Survey

The 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.

Post-Construction Inspection

Either the Utility Administrator or its contractor conducts an inspection to verify that the Sponsor has properly documented the installed equipment. After the inspection, the Utility Administrator either accepts or rejects the Installation Report based on the inspection results and project review.

Post-Construction Data Collection

The 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.

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 to. Continuous metering of post-construction variables are then used in the baseline and post-construction models to calculate baseline and post-construction energy use .

First Approach: Metering Post-Construction Energy Use and Variables

To calculate energy savings using the first approach, the Sponsor monitors demand and the same independent variables that were used for the System Baseline Model. The 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] =	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.

Second Approach: Metering Post-Construction Variables

To calculate energy savings using the second approach, the 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 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.

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

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[6] 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 2001 International Performance Measurement and Verification Protocol (IPMVP). More information on computer simulation analysis can be found in the IPMVP.

This approach requires that the Sponsor

1. Work with the Utility Administrator 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.

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[6] 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. The Utility Administrator reviews and verifies the savings estimates and simulation results.

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

Software Selection

The Utility Administrator recommends that the Sponsor use the most current version available of the DOE-2.1E hourly building simulation program. For projects with small projected incentive payments, the 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.

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 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.

Data Collection

The volume of data required for simulating a real building is significant. The Sponsor needs to collect data from the following sources:

- **As-built building plans**. The Sponsor should work with the building owner to gather as-built building plans.
- **Utility bills**. The 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 Sponsor may need to arrange for the installation of metering data to collect the necessary data. Also, the Sponsor should determine if building systems are sub-metered, and collect these data if available.
- **Conduct on-site surveys and reviews of mechanical plans.** The Utility Administrator helps the Sponsor establish which data must be collected. The Sponsor should visit the site to verify the accuracy of the mechanical plan data. The Utility Administrator may accompany the Sponsor during this survey. Depending on the project, the 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 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. In the M&V plan, the Sponsor should specify which weather data source is being 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).

Building Simulation Models

Once all necessary information is collected, the 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.

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.

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))[7]. 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

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

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

Acceptable tolerance for hourly data calibration is ± 30%

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.

[7] 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.

Next monthly-simulated energy consumption and monthly 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 = ± 25%

Equation 6.4 Error in annual energy consumption

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

Acceptable tolerance for monthly data calibration = ± 15%

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.

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.

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.

Project-Specific M&V Issues

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 is 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.