

IV

CenterPoint Energy 2007 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 2007 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 Projects

Overview

In the 2007 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 CenterPoint Energy 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 M&V guidelines provided in the following sections vary in detail and rigor, but fall into three general categories:

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

The 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 CenterPoint Energy 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 constant load motor are determined by comparing the rated efficiency of the specified, high-efficiency motor to that of a standard motor, and then conducting spot-metering of the motor'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	Energy Efficiency Measure	M&V Approaches Provided
1	Lighting (lamps, ballasts)	Deemed and simplified
2	High-efficiency cooling equipment	Deemed and simplified
3	High-efficiency motors—constant load	Simplified
4	Various	Simplified (utilizing stipulations)
5	Various variable load equipment	Full
6	Various complex measures	Full (utilizing simulation models)

Project Sponsors with specifications for equipment not covered by these M&V chapters should contact CenterPoint Energy 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 CenterPoint Energy as necessary, to develop an M&V methodology appropriate for each new construction project. M&V plans are not required for projects that use deemed savings for estimating all peak demand and energy savings. By choosing deemed savings, Project Sponsors agree to follow the procedures set-forth in this Program Manual to determine project savings. For projects requiring simplified or full M&V, the Project Sponsor must document the chosen methodology in an M&V plan, and submit that plan to CenterPoint Energy as part of the Final Application. It is the responsibility of the Sponsor to correct any deficiency in the M&V plan identified by CenterPoint Energy.

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

1. Describe the new construction project; include information on how the specified equipment exceeds applicable standards.
2. Identify – by chapter number and title – the approach(es) upon which the M&V methodology is based.
3. Describe the M&V methodology to be used. The methodology description should:
 - a. Identify the party responsible for performing M&V activities, including data analysis and documentation of results.
 - b. Explain in detail how calculations will be made. For instance, list analysis tools, such as DOE-2 computer simulations, and/or show the equations to be used. A complete method to indicate how collected survey and metering/monitoring data will be used to calculate savings should be defined. All equations should be shown.
 - c. Specify what metering equipment will be used, who will provide the equipment, and what the accuracy and calibration will be. Include a metering schedule describing metering times and duration, and how metering data will be validated and reported. Include data formats; electronic, formatted data, read directly from a meter or data logger are recommended for any short or long-term metering.
 - d. Define what key assumptions will be made about significant variables or unknowns. For instance: will actual weather data be used, rather than typical-year data? Describe any stipulations that will be made and the source of data for the stipulations.
 - e. Describe the sampling methodology: explain why sampling is appropriate, the size of the sample population and how the size is determined, and how sample points are chosen.
4. Explain how quality assurance will be maintained and replication confirmed. For example, will the data being collected be checked every month? Or, to ensure sufficient accuracy, will results be subject to third-party review?

1

M&V Guidelines for New Construction Lighting Efficiency Measures

1.1 Overview

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

This M&V procedure is not intended for use with lighting controls measures. Projects with daylighting controls or occupancy controls measures will be handled on a case-by-case basis. The Project Sponsor should work with CenterPoint Energy 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/ft²) for the type of building and the illuminated floor area (ft²). Energy savings are determined by multiplying the project's demand savings by the average operating hours for the building.

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

Stipulated Hours Method – Energy savings are based on whole building stipulated operating hours established for certain building types (See Table 1.2).

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

The method selected and the rigors of the M&V activities are functions 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.

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 detailing the fixtures actually installed. The Project Sponsor should fill out and submit survey results in the standard New Construction Lighting Survey Form using fixture codes provided in the Table of Standard Fixture Wattages. CenterPoint Energy or its contractor

will conduct a post-installation inspection to verify the installation of the specified equipment.

1.2 Stipulated Hours Method

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

1.2.1 Pre-Installation M&V Activities

1.2.1.1 Pre-Installation Equipment Specification

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

Some types of lighting fixtures are exempt from inclusion in the interior lighting demand calculation. Project Sponsors should list exempt fixtures in the separate sheet provided in the New Construction Lighting 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 applications¹:

- 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.

1.2.2 Post-Installation M&V Activities

1.2.2.1 Post-Installation Equipment Survey

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

1.2.2.2 Post-Installation Inspection

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

1.2.2.3 Lighting Power Allowance

Demand savings are based on the difference between a project's installed lighting load, compared to the maximum, code-specified lighting power allowance. To calculate the

maximum code-allowed lighting power allowance for a building, multiply the maximum lighting power density for the appropriate building type, as listed in Table 1.1, by the gross lighted floor area of the building. If a lighting measure is planned for a building type not 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 Type²

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

1.2.2.4 Operating Hours

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

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	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	4,772	87%	10%	5%
Non 24-Hour Supermarket/Retail/Restaurant	4,250	95%	10%	5%
Office	3,760	80%	10%	5%
Parking Structure	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 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 and the kW reduction determined from the Table of Standard Fixture Wattages.

1.2.3 Calculation of Demand and Energy Savings

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

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.

1.2.3.1 Peak Demand Savings

Equation 1.1:

$$\text{Connected Lighting Load Reduction [kW]} = (\text{Lighting Power Density [W/ft}^2\text{]} * \text{Gross Lighted Floor Area [ft}^2\text{]} * .001 [\text{kW/W}]) - \text{Installed Interior Lighting Load [kW]}$$

Equation 1.2:

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

Equation 1.3:

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

1.2.3.2 Energy Savings

Equation 1.4:

$$\text{Lighting Energy Savings [kWh]} = \text{Connected Lighting Load Reduction [kW]} * \text{Annual Operating Hours [hrs]}$$

Equation 1.5:

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

Equation 1.6:

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

1.2.4 Example

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

Example

High-efficiency lighting systems are proposed for a large office building project scheduled for construction in the next year. The office building will have a gross lighted floor area of 170,251 ft². 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/ft². 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	85.5	3,760
Conference Rooms	20	9.6	3,760
Task Lamps	24	4.8	3,760
Private Offices	44	53.2	3,760
Restrooms	20	2.8	3,760
Total	200	157.9	

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

(a) Connected Lighting Load Reduction = $(1.3 \text{ W/ft}^2 * 70,251 \text{ ft}^2 * .001 \text{ kW/W}) - 74.8 \text{ kW}$
= 63.4 kW

(b) Interactive HVAC Demand Savings = $63.4 \text{ kW} * 0.10$
= 6.3 kW

(c) Total Demand Savings = $(63.4 \text{ kW} + 6.3 \text{ kW}) * 0.80$
= 55.8 kW

(d) Lighting Energy Savings = $55.8 \text{ kW} * 3,760 \text{ hours}$
= 209,808 kWh

(e) Interactive HVAC Energy Savings = $209,808 \text{ kWh} * 0.05$
= 10,490 kWh

(f) Total Energy Savings = $209,808 \text{ kWh} + 10,490 \text{ kWh}$
= 220,298 kWh

1.3 Metered Hours Method

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

1.3.1 Pre-Installation M&V Activities

1.3.1.1 Pre-Installation Equipment Survey

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

Some types of lighting fixtures are exempt from inclusion in the interior lighting demand calculation. Project Sponsors should list exempt fixtures in the separate sheet provided in the M&V New Construction Lighting 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 applications³:

- 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.

³ Reference: ASHRAE 90.1-1999, Section 9.3.1.

- 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.

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

1.3.2 Post-Installation M&V Activities

1.3.2.1 Post-Installation Equipment Survey

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

1.3.2.2 Post-Installation Inspection

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

1.3.2.3 Post-Installation Operating Hours

After the lighting equipment has been installed and the facility is occupied, the Project Sponsor conducts short-term metering of the operating hours for a random sample of fixtures in each usage group. As part of the FA review and approval, CenterPoint Energy 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 1.4. 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 Project Sponsor should extrapolate results from the monitored sample to the population to calculate the average lighting operating hours for every unique usage group. Simple, unweighted averages of operating hours should be calculated for each usage group using Equation 1.7. The Project Sponsor should use these average operating hours to calculate the energy savings for each respective usage group.

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

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

Where:

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

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

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

Equation 1.8: Calculation of coincidence factor for a usage group

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

Where:

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

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

1.3.3 Calculation of Demand and Energy Savings

The peak demand savings and energy savings are calculated according to Equations 1.1 through 1.6, and Equations 1.9 and 1.10 below. The hours of operation should be calculated for each usage group and also for each season in which the usage groups’ operating hours may vary (as for schools). The annual hours of operation are determined by adding together the operating hours that are calculated for each season. If the operating hours do not vary seasonally, use one year as the “season.” 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.

1.3.3.1 Hours of Operation (see Equation 1.7 above)

Equation 1.9:

$\text{Seasonal Hours of Operation [hrs]} = \frac{\text{Hours Lights On}}{\text{Hours Lights Metered}} * \text{Hours in Season}$
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Equation 1.10:

$\text{Annual Hours of Operation [hrs]} = \text{Sum of \{Seasonal Hours of Operation [hrs]\}}$
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1.3.3.2 Peak Demand Savings

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

1.3.3.3 Energy Savings

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

1.3.4 Example

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

Example

A 80,000 ft², 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	[19/90] = 0.21
Admin. Offices	14.4	[106/504] * 8,760 = 1,842	[23/90] = 0.26
Restrooms	9.6	[225/504] * 8,760 = 3,911	[38/90] = 0.42
Shop	4.8	[314/504] * 8,760 = 5,458	[44/90] = 0.49
Continuous	41.2	[410/504] * 8,760 = 7,126	[60/90] = 0.67
Total	72.0	Weighted Avg. = 5,422	Weighted Avg. = 0.53

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

- (a) Connected Lighting Load Reduction = $(1.2 \text{ W/ft}^2 * 80,000 \text{ ft}^2 * .001 \text{ kW/W}) - 72.0 \text{ kW}$
= 24.0 kW
- (b) Interactive HVAC Demand Savings = $24.0 \text{ kW} * 0.10$
= 2.4 kW
- (c) Total Demand Savings = $(24.0 \text{ kW} + 2.4 \text{ kW}) * 0.53$
= 14.0 kW**
- (d) Lighting Energy Savings = $24.0 \text{ kW} * 5,422 \text{ hours}$
= 130,128 kWh
- (e) Interactive HVAC Energy Savings = $130,128 \text{ kWh} * 0.05$
= 6,506 kWh
- (f) Total Energy Savings = $130,128 \text{ kWh} + 6,506 \text{ kWh}$
= 136,634 kWh**

2

M&V Guidelines for High-Efficiency Cooling Equipment in New Construction

2.1 Overview

Cooling equipment measures must 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 high-efficiency cooling equipment. High-efficiency equipment for which savings may be measured using the methods described in this chapter include:

- 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)
- Fuel switching from electric to gas engine-driven cooling equipment

The projects should have the following characteristics:

- Documented cooling load calculations for the affected facility.
- The scope of the project for which incentives are requested is limited to individual pieces of equipment, e.g. two 500-ton chillers, and not entire building systems.

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 efficiencies for new construction cooling equipment are from ASHRAE Standard 90.1-1999; these values are provided in the Standard Cooling Equipment Tables in Appendix A of this document. The applicable column in the Standard Cooling Equipment Tables is titled “Minimum Performance Standard”.

2.2 Deemed Savings for Cooling Equipment

The *deemed savings* approach to M&V for cooling equipment as part of new construction is available to sponsors. The deemed savings methodology is incorporated in an Excel spreadsheet, available to sponsors, which calculates savings values based on user inputs. The spreadsheet was developed as a tool to assist sponsors with the deemed savings method. Manual calculations using Equations 2.1 and 2.2 (below) are acceptable as well. Projects that are eligible to use the deemed savings approach meet the following requirements:

- The installed cooling equipment is electric.
- 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.

The following measure is excluded from consideration in the program:

- Cooling equipment retrofits that do not produce a measurable and verifiable electric demand reduction during the peak summer period or reduce electricity consumption – redundant equipment.

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

Building Type	Description
Religious Worship	A religious worship building that experiences full operation on Sundays, and a partial schedule on weekdays and Saturdays.
College	A multi-story college building that operates a full day five days per week and a partial day on weekends.
Convenience	A small convenience store that operates 24 hours per day, 7 days per week.
Fast-Food	A small fast food restaurant that operates a full day, seven days per week. Generally smaller than 3,000 sq. ft.
Grocery	Typical supermarket that operates between 16 and 24 hours per day, 7 days per week.
Hospital	A multi-story hospital building that operates 24 hours per day, 7 days per week.
Hotel	A typical multi-story hotel that operates 24 hours per day, 7 days per week. Usually larger than 50,000 sq. ft.
Motel	A low rise motel that operates 24 hours per day, 7 days per week. Usually smaller than 50,000 sq. ft.
Nursing Home	An assisted care facility that operates 24 hours per day, 7 days per week.
Office, Large	Typical multi-story office building that operates 12 to 16 hours per day, Monday through Friday, a half day on Saturday and a few hours on Sunday. Applicable for buildings greater than 50,000 sq. ft.
Office, Small	Typical low rise office building that is operated mostly Monday through Friday and a minimal number of hours on Saturday and Sunday. Applicable for buildings up to 50,000 sq. ft.
Public Assembly	A large public assembly building that operates on a partial schedule all days.
Retail	Retail store that operates typical business hours Monday through Saturday and a reduced day on Sundays.
Restaurant	Typical small restaurant operating full day six days per week with a reduced schedule on Sundays. Generally larger than 3,000 sq. ft.
School	A low rise elementary or high school that operates all day Monday through Friday, 50 weeks per year.

Service	A light commercial building that operates a full day six days per week. Examples include beauty parlors, automotive shops and so on.
Warehouse, Non Refrig.	A conditioned warehouse, not refrigerated, that operates 24 hours/ day, 7 days per week.

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

2.2.1 Pre-Installation M&V Activities

2.2.1.1 Pre-Installation Site Survey

Prior to installing the cooling equipment measures, the Project Sponsor prepares a pre-installation equipment specification sheet by filling out the deemed savings spreadsheet. The deemed savings spreadsheet is available for downloading from the program Web site, www.centerpointcisop.com. The deemed savings spreadsheet requires the Project Sponsor to input information about the equipment and the specified equipment’s type, size, make/ model and efficiency. The Project Sponsor submits the deemed savings spreadsheet as part of the Final Application.

2.2.1.2 Pre-Installation 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 CenterPoint Energy’s discretion.

2.2.2 Post-Installation M&V Activities

2.2.2.1 Post-Installation Equipment Survey

Once the construction project is complete, the Project Sponsor revises the deemed savings spreadsheet as necessary to reflect as-built conditions. An updated copy of the deemed savings spreadsheet should be included with the Installation Report.

The Project 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 full load performance of the equipment.

2.2.2.2 Post-Installation Inspection

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

2.2.3 Deemed Savings Calculations

The deemed savings methodology involves the application of two mathematical equations shown in Equation 2.1 and Equation 2.2. The deemed savings spreadsheet uses these equations to calculate savings automatically. Cooling equipment installed as new construction must meet or exceed ASHRAE 90.1 – 1999 minimum efficiency. For the purpose of deemed savings, the “baseline” efficiency of the new equipment is assumed to be

the required minimum efficiency of the particular size and type of equipment. Peak demand and energy savings are calculated using the actual efficiency of the new cooling equipment. Installing a chiller with only the minimum efficiency will not qualify for incentives.

Equation 2.1: Calculation of peak demand savings for cooling equipment

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

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 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 building type and new equipment type
$\eta_{\text{post-installation}}$	=	Rated efficiency of the installed equipment (kW/Ton)

Equation 2.2: Calculation of energy savings for cooling equipment

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

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 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 building type and new equipment type
$\eta_{\text{post-installation}}$	=	Rated efficiency of the installed equipment (kW/Ton)

To calculate savings by hand for cooling equipment measures using the deemed savings methodology, follow these steps:

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

Use the following conversions to get kW/Ton where necessary⁴:

$$\text{kW/ton} = 12 / \text{EER}$$

$$\text{kW/ton} = 3.517 / \text{COP}$$

$$\text{kW/ton} = 12 / (\text{SEER} * 0.697 + 2.0394)$$

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.

⁴ The conversion from SEER to kW/ton is an approximation based on published data from the Carrier Corporation

Example

A 200-ton air-cooled chiller serving a small office is being installed in Houston, TX.

- Step 1 The Sponsor finds the appropriate baseline efficiency from Appendix A, Table A.7. A 200-ton air-cooled chiller has a COP of 2.8. Using the conversion, $\text{kW/Ton} = 3.517/\text{COP}$, the sponsor finds that $\eta_{\text{baseline}} = 1.256 \text{ kW/Ton}$.
- Step 2 The manufacturer's data for the new equipment shows that the $\text{COP} = 3.0$. Using the conversion, $\text{kW/Ton} = 3.517/\text{COP}$, the sponsor finds that $\eta_{\text{post-installation}} = 1.172 \text{ kW/Ton}$.
- Step 3 The baseline and new chiller are each 200-ton units.
- Step 4 The sponsor looks in Appendix A, Table A.10 to find the appropriate coefficients. The demand coefficient for a small office building with an air-cooled chiller in Houston is 0.81, so $a = b = 0.81$. The energy coefficient for a small office building with an air-cooled unit in Houston is 1,860, so $c = d = 1,860$.
- Step 5 By inserting the information gathered in Steps 1-4 into Equations 3.1 and 3.2, the Sponsor calculates the savings:

$$kW_{\text{savings}} = 200 * (0.81 * 1.256 - 0.81 * 1.172) = 13.6 \text{ kW}$$

$$kWh_{\text{savings}} = 200 * (1,860 * 1.256 - 1,860 * 1.172) = 31,248 \text{ kWh}$$

2.3 Simplified M&V – Limited Measurement

The simplified M&V procedure for cooling equipment involves collecting one year of consumption data after the project is complete. To determine demand savings for new electric cooling equipment, the maximum 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.

For gas engine-driven cooling equipment, the Sponsor must establish a “baseline” peak demand and annual energy usage for a similarly sized electric chiller serving the exact same load. This can be done two ways. The Sponsor can provide a year of measured data for a same size electric chiller installed in an exactly identical facility, or with a computer model. The same requirements for any model discussed elsewhere in this manual apply in this case. The Sponsor must establish the baseline to the satisfaction of CenterPoint Energy.

2.3.1 Pre-Construction M&V Activities

2.3.1.1 Equipment Survey

As part of the application process, the Project Sponsor provides an inventory of *all* specified cooling equipment by filling out the Cooling Equipment Inventory Form, available for downloading from the program Web site at www.centerpointcisop.com. The information provided should include:

- equipment type
- year
- make/model
- rated capacity
- rated efficiency
- operating schedule
- operating sequence

2.3.1.2 Site Inspection

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

2.3.2 Post-Installation M&V Activities

2.3.2.1 Equipment Survey

After construction is complete, the Project Sponsor provides an updated Cooling Equipment Inventory Form to CenterPoint Energy 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 full load performance of the equipment.

2.3.2.2 Site Inspection

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

2.3.2.3 Performance Monitoring

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

For electric-to-gas fuel switching cooling equipment, twelve months of post-installation gas usage is required in the simple M&V procedure. In situations where the “baseline” equipment and new construction equipment are not similar (water-cooled vs. air-cooled), the Sponsor must account for the peak demand and annual energy usage of any auxiliary equipment.

2.3.3 Calculation of Demand and Energy Savings

2.3.3.1 High-efficiency Cooling Equipment

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

Peak demand and energy savings are calculated according to Equation 2.3 and Equation 2.4, respectively.

Equation 2.3 Peak Demand Savings

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

Where:

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

Equation 2.4 Energy Savings

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

Where:

- kWh_{meter} = Summed metered kWh cooling equipment energy use determined for one year.
- COP_{new} = 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 CenterPoint Energy 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 (0.533 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 CenterPoint Energy'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 TMY and **2675 °F** day for the metering year.

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

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

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

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

The energy savings are determined as follows:

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

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

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

2.3.3.2 Electric to Gas Equipment (Fuel switching)

Incentive payments based on demand and energy savings are made for electric-to-gas fuel switching projects. Demand savings are allowed only for equipment that operates on weekdays between the hours of 1 P.M. and 7 P.M. Monday through Friday for the months of May through September. Peak demand savings are calculated according to Equation 2.5.

Equation 2.5: Peak Demand Savings for Fuel Switching Measures

$$\Delta kW = kW_{\text{meter}} - kW_{\text{new equip}}$$

Where:

kW_{meter} = Maximum electric cooling equipment demand measured during the utility peak-demand period (measured or predicted)

$kW_{\text{new equip}}$ = Maximum demand of any new electric auxiliary equipment installed with the gas engine chiller measured during the utility peak-demand period

Energy savings are calculated by subtracting the new fuel consumption (converted to kWh using a heat rate of 10,500 Btu/kWh) from the baseline energy consumption. Energy savings are calculated according to Equation 2.6.

Equation 2.6: Energy Savings for Fuel Switching Measures

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

Where:

kWh_{meter} = Electric cooling equipment annual energy consumption (measured or predicted)

$kWh_{\text{new equip}}$ = Annual energy usage of any new electric auxiliary equipment installed with the gas engine chiller (measured or predicted)

Btu_{gas} = Measured annual post-retrofit gas consumption

3

M&V Guidelines for Constant Load Motor Measures in New Construction

3.1 Overview

This chapter presents the simplified M&V approach for projects involving the installation 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 to be the same for both baseline and higher-efficiency motors.

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

3.2 Pre-Construction Activities

3.2.1 Equipment Survey

Project Sponsors should use the Motor and VSD Inventory form to record the following information for each specified high-efficiency motor:

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

3.2.2 Site Inspection

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

3.3 Post-Construction Activities

3.3.1 Equipment Survey

The Project Sponsor provides a post-construction equipment survey, similar to the pre-construction equipment survey, to CenterPoint Energy as part of the Installation Report. The updated Motor and VSD Inventory Form reflects the actual, as-built conditions of the project.

3.3.2 Motor Demand Measurement

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

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

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

3.3.4 Site Inspection

After CenterPoint Energy receives an Installation Report, either CenterPoint Energy 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. CenterPoint Energy will require the Project Sponsor to make any necessary corrections to the Installation Report based on the results of the inspection.

3.4 Calculation of Motor Operating Hours

After CenterPoint Energy 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]	$= \frac{\text{Motor on-time during metering period (hrs)}}{\text{Length of metering period (hrs)}} * 8760 \text{ hrs/yr}$

For projects 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, CenterPoint Energy 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.

3.5 Calculation of Peak Demand and Energy Savings

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

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

Equation 3.3 Peak Demand Savings

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

Equation 3.4 Energy Savings

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

The Project Sponsor reports the peak demand and energy savings to CenterPoint Energy 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, 4-pole, 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:

$$\text{Baseline motor demand} = 117.9 * (0.96/0.945) = 119.8 \text{ kW}$$

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:

$$\text{Annual operating hours} = (81/168)*8760 = 4,224 \text{ hrs}$$

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

$$\text{Peak demand savings} = 119.8 \text{ kW} - 117.9 \text{ kW} = \mathbf{1.9 \text{ kW}}$$

$$\text{Annual energy savings} = 1.9 \text{ kW} * 4224 \text{ hrs} = \mathbf{8,026 \text{ kWh}}$$

4

Measurement and Verification Using Stipulated Savings Factors

4.1 Overview

Measurement and verification (M&V) using stipulated savings factors involves comparing the efficiency of a new construction project to the efficiency of a project that meets the minimum requirements of the building code and then 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:

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

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

Any Project Sponsor considering the use of stipulated savings factors should consult with CenterPoint Energy 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).

4.1.1 Data Types

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

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

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

4.2 Documenting Baseline Characteristics

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

- The Project Sponsor prepares a pre-construction equipment inventory.
- Either CenterPoint Energy or its contractor performs a pre-construction inspection, if necessary.
- The Project Sponsor develops stipulated savings factors.

4.2.1 Pre-Construction Equipment Inventory

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

4.2.2 Pre-Construction Inspection

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

4.2.3 Development of Stipulated Savings Factors

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

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

4.2.4 Compliance with Energy Standards

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

- Baseline equipment should meet *prescriptive* efficiency standard requirements for affected equipment (e.g., ASHRAE Standard 90.1).
- The baseline need not comply with performance compliance methods that require the project site to meet an energy budget.
- Minimum state and federal energy efficiency standards or codes must be incorporated into the baseline.

4.3 Documenting Post-Construction Characteristics

When construction is complete, the following steps are taken:

- The Project Sponsor conducts an equipment inventory.
- Either CenterPoint Energy or its contractor conducts an inspection.
- The Project Sponsor verifies stipulated savings factors using data from the installed system.

4.3.1 Post-Construction Equipment Survey

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

4.3.2 Post-Construction Inspection

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

4.3.3 Verification of Stipulated Savings Factors

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

4.4 Calculation of Demand and Energy Savings

Once the equipment installation is verified and the proposed stipulated savings factors have been approved by CenterPoint Energy, the Project Sponsor must calculate the demand and

energy savings generated by the project. The best approach for calculating the project's savings depend on the type of project and the data collected, but, in general, actual metered/measured equipment operating data should be used as much as possible.

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

Equation 4.1 Demand Savings	
Demand Savings [kW]	= kW _{Baseline} - kW _{Post-installation}
Where:	
<i>KW_{Baseline}</i>	= Baseline equipment demand as predicted during the utility peak, summer coincident load period.
<i>KW_{Post-Installation}</i>	= Installed equipment demand as measured by short-term metering during the utility peak, summer coincident load period.

Equation 4.2 Annual energy savings, stipulated hours	
Annual Energy Savings [kWh]	= (kW _{Baseline} - kW _{Post-installation}) * Hours _{Stipulated}
Where:	
<i>KW_{Baseline}</i>	= Baseline equipment demand as predicted during the utility peak, summer coincident load period.
<i>KW_{Post-Installation}</i>	= Installed equipment demand as measured by short-term metering during the utility peak, summer coincident load period.
<i>Hours_{Stipulated}</i>	= Annual operating hours determined using stipulated factor.

4.5 Project-Specific M&V Issues

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

- How accurately stipulated factors will reflect actual energy savings
- How well the stipulated factors are supported by other data sources, e.g. physical observations, 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 in New Construction

5.1 Overview

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

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

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

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

The M&V method described here is based on Option B of the 2001 International Performance Measurement and Verification Protocol (IPMVP). More details on this method can be found in the IPMVP.

5.2 Documenting Baseline Characteristics

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

1. The Project Sponsor conducts a pre-construction equipment inventory.

2. Either CenterPoint Energy or its contractor conducts a pre-construction inspection, if necessary.
3. The Project Sponsor develops a baseline energy consumption model.

5.2.1 Pre-Construction Equipment Survey

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

5.2.2 Pre-Construction Inspection

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

5.2.3 Baseline Model Development

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

Project Sponsors should use manufacturer-supplied performance data for equipment that meets the minimum requirements of code to establish a 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 the model is statistically valid.

The criteria for establishing statistical validity of the model are:

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

- All data entered into the model are thoroughly documented and model limits (range of independent variables for which the model is valid) are specified.

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

5.2.4 Compliance with Energy Standards

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

- Baseline equipment characterization meets prescriptive efficiency standards requirements for affected equipment (e.g., ASHRAE Standard 90.1).
- Baseline need not comply with performance compliance methods that require the project site to meet an energy budget.
- Minimum state and federal energy efficiency standards or codes must be incorporated into the baseline.

5.3 Documenting Post-Construction Characteristics

When construction is complete, the following steps are taken:

1. The Project Sponsor updates the equipment inventory.
2. Either CenterPoint Energy or its contractor conducts an inspection.
3. The Project Sponsor conducts any necessary data collection.

5.3.1 Post-Construction Equipment Survey

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

5.3.2 Post-Construction Inspection

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

5.3.3 Post-Construction Data Collection

The Project Sponsor must monitor one or both of the following variables simultaneously:

- **Independent variables that affect energy use.** Examples of such data are ambient temperature, control outputs, flow rate, cooling tons, and building occupancy.
- **System energy consumption.** Energy demand (kW) of installed equipment, metered over a time period representative of the full range of system operation.

The variable(s) monitored depend on the variable(s) modeled in the Baseline System Model.

5.4 Calculation of Demand and Energy Savings

There are two approaches for calculating demand and energy savings from generic variable load projects. Both approaches require baseline modeling (as previously discussed) and post-construction metering.

The first approach requires continuous metering of demand and the independent variables used in the baseline model. Post-construction variable data are used with the baseline model to calculate baseline energy use.

The second approach involves developing a post-construction model from short-term metering of demand and continuous metering of independent variables. Data from continuous metered post-construction variables are then used in the baseline and post-construction models to calculate baseline and post-construction energy use.

5.4.1 First Approach: Metering Post-Construction Energy Use and Variables

To calculate energy savings using the first approach, the Project Sponsor monitors demand and the same independent variables that were used for the System Baseline Model. The Project Sponsor then inputs the post-construction independent variable data to the System Baseline Model and compares post-construction energy use with baseline energy use. Demand and energy savings, over a single observation interval, are calculated using Equations 5.1 through 5.3.

Equation 5.1 Demand Savings	
Demand Savings [kW]	= kW _{Baseline,Max} - kW _{Measured,Max}
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.

Equation 5.2 Energy Savings	
Energy Savings _i [kWh]	= (kW _{Baseline, i} - kW _{Measured, i}) * T _i
Where:	
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.

Equation 5.3 Annual Energy Savings	
Annual Energy Savings [kWh]	= Sum of (Energy Savings) _i

5.4.2 Second Approach: Metering Post-Construction Variables

To calculate energy savings using the second approach, the Project Sponsor must first develop a Post-Construction System Model for use as a proxy for direct post-construction energy use measurement. Then, the Project Sponsor monitors the relevant independent variables and uses that data to estimate post-construction energy use. Once the post-construction energy use is estimated, energy savings over the course of a single observation interval will be calculated using the following Equations 5.4 through 5.6.

Equation 5.4 Demand Savings	
Demand Savings [kW]	= kW _{Baseline,Max} - kW _{Post-Installation,Max}
Where:	
kW _{Baseline,Max}	= Maximum baseline equipment demand occurring during utility peak, summer, coincident load period.
kW _{Post-Installation,Max}	= Maximum, post-construction equipment demand occurring during utility peak, summer, coincident load period.

Equation 5.5 Energy Savings	
$\text{Energy Savings}_i \text{ [kWh]} = (\text{kW}_{\text{Baseline}, i} - \text{kW}_{\text{Post-Installation}, i}) * T_i$	
Where:	
$\text{kW}_{\text{Baseline}, i}$	= Baseline kW calculated from Baseline System Model and corresponding to same time interval, system output, weather, etc., conditions as $\text{kW}_{\text{Post-Installation}, i}$.
$\text{kW}_{\text{Post-Installation}, i}$	= 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.

Equation 5.6 Annual Energy Savings	
Annual Energy Savings [kWh] =	Sum of (Energy Savings) _i

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

5.5 Project-Specific M&V Issues

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

- Determination of post-construction metering approach—i.e., metering of energy use or post-construction variables.
- Modeling methodology for Baseline System Model and Post-Construction Model (if used).
- Identification of appropriate independent variables.
- Duration of post-construction metering.

6

Measurement and Verification Using Calibrated Simulation Analysis

6.1 Overview

This section outlines the use of computer simulation analysis for measurement and verification of new construction energy savings. Computer simulation analysis should be used when the energy impacts of the energy efficiency measures are too complex⁵ 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 Project Sponsor

1. Work with CenterPoint Energy 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.

⁵ Wolpert, J.S. and J. Stein, "Simulation, Monitoring, and the Design Assistance Professional," 1992 International Energy and Environment Conference.

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.
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. CenterPoint Energy reviews and verifies the savings estimates and simulation results.

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

6.2 Software Selection

CenterPoint Energy recommends that the Project Sponsor use the most current version available of the DOE-2.1E hourly building simulation program. For projects with small projected incentive payments, the Project Sponsor may use another program, provided that the program can be shown to adequately model the building, the system or equipment installations can be calibrated to a high level of accuracy, and the calibration can be documented.

6.3 Developing a Calibrated Simulation Strategy

A sound approach to measuring and verifying your savings using computer simulation analysis must include the activities listed below. The Project Sponsor and CenterPoint Energy 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 built, had minimum standard equipment been installed instead of the high-efficiency equipment.
- Define the as-built building, which represents the 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 because there

are more data points to compare. If monthly billing data are used, then spot or short-term data measurements for calibrated key values may be used.

- Specify spot and short-term measurements to be taken of building systems. These measurements augment the whole-building data and enable the modeler to accurately characterize building systems. Spot and short-term measurements are valuable, but may add significant cost and time to the project.

6.4 Data Collection

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

- **As-built building plans.** The Project Sponsor should work with the building owner to gather as-built building plans.
- **Utility bills.** The Project Sponsor should collect utility bills for a *minimum* of twelve consecutive months following construction. The billing data should include monthly consumption (kWh) and peak electric demand (kW), preferably in fifteen-minute or hourly intervals (for optimal calibration). If interval data are not available, the Project Sponsor may need to arrange for the installation of metering equipment to collect the necessary data. Also, the Project Sponsor should determine if building systems are sub-metered, and collect these data if available.
- **Conduct on-site surveys and reviews of mechanical plans.** CenterPoint Energy helps the Project Sponsor establish which data must be collected. The Project Sponsor should visit the site to verify the accuracy of the mechanical plan data. CenterPoint Energy may accompany the Project Sponsor during this survey. Depending on the project, the Project Sponsor should collect data for
 - primary HVAC equipment (e.g. chillers and boilers): capacity, number, model and serial numbers, operation schedules
 - secondary HVAC equipment (e.g., air handling units, terminal boxes): fan sizes and types, motor sizes and efficiencies, design flow rates and static pressures, duct system types, economizer operation and control
 - HVAC controls, including the location of zones, temperature set-points, control set-points and schedules, and any special control features
 - building envelope and thermal mass: dimensions and type of interior and exterior walls, properties of windows, and building orientation and shading
 - lighting systems: number and types of lamps, with nameplate data for lamps and ballasts, lighting schedules
 - plug loads: summarize major and typical plug loads for assigning values per zone
 - occupancy: population counts, occupation schedules in different zones

- other major energy consuming loads: type (industrial process, air compressors, water heaters, elevators), energy consumption, schedules of operation
- **Interview operators.** Building operators can provide much of the above listed information and can also inform on any deviation in the intended operation of equipment.
- **Make spot measurements.** To determine the actual power draw of operating equipment, the Project Sponsor may find it necessary to meter certain circuits (lighting, plug load, HVAC equipment).
- **Conduct short-term measurements.** Data-logging equipment may be set up to record system data as they vary over time. 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 Project Sponsor should specify which weather data sources will be used.

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

6.5 Building Simulation Models

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

6.5.1 Calibration

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

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

6.5.1.1 Hourly Data Calibration

In hourly calibration, two statistical indices are required to declare a model calibrated: monthly mean bias error (MBE) and the coefficient of variation of the root mean squared error ($C_v(\text{RMSE})$)⁶. Equation 6.1 is used to calculate MBE, and Equation 6.2 is used to calculate $C_v(\text{RMSE})$.

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 $\pm 10\%$.

⁶ 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. Thamilsaran, "Predicting Hourly Building Energy Use: The Great Energy Predictor Shootout II, Measuring Retrofit Savings – Overview and Discussion of Results, ASHRAE Transactions, June, 1996.

Equation 6.2 Coefficient of variation of the root mean squared error

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

Where:

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

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

N_{hr} = the number of hours in the month

Acceptable tolerance for hourly data calibration is $\pm 30\%$

6.5.1.2 Monthly Data Calibration

Comparing simulated energy use to monthly utility bills is straightforward. First, the model is developed and run using weather data that correspond to the monthly utility billing periods. Next, monthly simulated energy consumption 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 = $\pm 25\%$

Equation 6.4 Error in annual energy consumption

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

Acceptable tolerance for monthly data calibration = $\pm 15\%$

6.5.1.3 Baseline Models

After calibrated simulation of the as-built model, the baseline model can be prepared. The baseline model is usually the as-built model with the substitution of minimum energy standards for equipment and systems. This new baseline model should also be documented.

6.5.1.4 Minimum Energy Standards

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

- Baseline equipment/systems should not include devices (such as lamps and ballasts) that are not allowed under current regulations.
- Baseline equipment models should meet *prescriptive* efficiency standards for affected equipment. These requirements are found in either ASHRAE 90.1 1999 or local/federal energy codes. The applicable standard requiring the highest efficiency should be used.
- Baseline calculations *do not* have to comply with *performance compliance* methods that require the project site to meet an energy budget.

6.5.1.5 Detailed Energy Savings Calculations

Energy savings are determined from the difference between the outputs of the baseline and as-built models. Savings are determined with both models using the same conditions (weather, occupancy schedules, etc.). To calculate savings, the energy consumption projected by the as-built model is subtracted from energy consumption projected by the baseline model. Equation 6.5 is used to calculate energy savings.

Equation 6.5 Energy savings calculation

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

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.
$kWh_{\text{As-Built}}$	=	The kilowatt-hour consumption of the as-built building operating under the same conditions (weather, operation and occupancy schedules, etc.) as the baseline building.

6.6 Project-Specific M&V Issues

Project Sponsors who are using the computer simulation analysis approach must include the following in their project-specific M&V plans:

- Identification of which version of DOE-2 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 incorporation of state and federal standards in the baseline model.
- 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.