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 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.

For some projects, the data required to develop the baseline model are not available prior to construction. For such projects, it may be possible to first install the equipment, develop the post-construction model, and then adjust the post-construction model to establish a baseline model. In creating the baseline model from the post-construction model, the Sponsor must substitute minimum standard equipment efficiencies listed in ASHRAE 90.1-1999 for the actual efficiencies of the installed equipment.

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

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

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

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

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

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

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

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

Where:

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

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

Equation 5.5 Energy Savings

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

Where:

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

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

T_i = Length of time interval.

Equation 5.6 Annual Energy Savings

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

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.