7 Measurement and Verification for Generic Variable Loads

7.1 Overview

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

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

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

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

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

The M&V method described here is based on Option B of the 1997 International Performance Measurement and Verification Protocol (IPMVP). Valuable insights on this method can be found in the IPMVP.

7.2 Documenting Baseline Operating Characteristics

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

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

7.2.1 Pre-installation Equipment Survey

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

7.2.2 Pre-installation Inspection

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

7.2.3 Pre-installation Data Collection

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

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

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

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

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

7.2.4 Baseline Model Development

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

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

The criteria for establishing statistical validity of the model are:

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

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

7.3 Compliance with Energy Standards

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

- Baseline equipment characterization should meet prescriptive efficiency standards requirements for affected equipment (e.g., ASHRAE Standard 90.1);
- The baseline does not have to comply with performance compliance methods that require the project site to meet an energy budget; and

- Demand and energy savings should be calculated with the incorporation of minimum state and federal energy efficiency standards or codes into the determination of baseline energy use.

7.4 Documenting Post-installation Operating Characteristics

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

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

7.4.1 Post-installation Equipment Survey

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

7.4.2 Post-installation Inspection

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

7.4.3 Post-installation Data Collection

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

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

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

7.5 Calculation of Demand and Energy Savings

There are two approaches for calculating demand and energy savings from generic variable load projects. Both approaches require pre- and post-installation metering. The pre-installation metering includes short-term measurements of equipment demand and

metering of independent variables. The pre-installation metering is necessary to develop the baseline energy use model.

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

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

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

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

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

Equation 7.1:

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

Equation 7.2:

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

Equation 7.3:

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

Where:

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

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

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

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

T_i = Length of time interval.

7.5.2 Second Approach: Metering Post-installation Variables

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

Equation 7.4:

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

Equation 7.5:

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

Equation 7.6:

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

Where:

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

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

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

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

T_i = Length of time interval.

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

7.6 Project-Specific M&V Issues

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

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