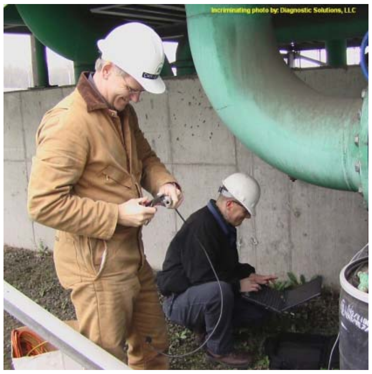

End-Use Metering Absent Baseline Measurement: An M&V Protocol Application Guide

May 2012

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Prepared for

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Contract Number 00044680

Table of Contents

1. Introduction

1.1. Purpose

This document presents *End-Use Metering Absent Baseline Measurement: An M&V Protocol Application Guide*[1] as a complement to the Measurement & Verification (M&V) protocols used by the Bonneville Power Administration (BPA). This *Absent Baseline Application Guide* assists the engineer in applying the *Verification by Equipment or End-Use Metering Protocol*[2] to verify savings from energy-efficient equipment installed in situations where the baseline for the measure is not the equipment or processes in place prior to the measure's installation. This protocol applies to newly constructed facilities and major additions to an existing facility. The protocol can apply to replacement of failed equipment where the opportunity to measure the baseline has passed or the prior equipment is outdated and does not constitute the appropriate baseline. As is the case for the *End-Use Metering Protocol*, this protocol is intended for measures that change load or operating hours, or both load and hours. Savings can be large or small. The protocol can handle non-interactive measures and interactive measures in some circumstances. It is adherent with *IPMVP Options A and B.*

.This document is one of many produced by BPA to direct M&V activities. The *Measurement and Verification (M&V) Protocol Selection Guide and Example M&V Plan* provides the region with an overview of all of BPA's M&V protocols, application guides, and reference guides, and gives direction as to the appropriate document for a given energy efficiency project. The document *Glossary for M&V: Reference Guide* defines terms used in the collection of BPA M&V protocols and guides.

Chapter 7 of this guide provides full citations (and web locations, where applicable) of documents referenced.

1.2. Background

In 2009, BPA contracted with a team led by Research Into Action, Inc. to assist the organization in revising the M&V protocols it uses to assure energy savings for the custom projects it accepts from its customer utilities. The team has conducted two phases of research and protocol development under the contract, Number 00044680.

In the first phase, Research Into Action directed a team comprised of:

- Quantum Energy Services & Technologies, Inc. (QuEST), led by David Jump, Ph.D., PE and assisted by William E. Koran, PE;
- Left Fork Energy, Inc., the firm of Dakers Gowans, PE;

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1 Hereinafter, *Absent Baseline Application Guide.*

2 Hereinafter, *End-Use Metering Protocol.*

- Warren Energy Engineering, LLC, the firm of Kevin Warren, PE;
- Schiller Consulting, Inc., the firm of Steven Schiller, PE; and
- Stetz Consulting, LLC, the firm of Mark Stetz, PE.

In the second phase, Research Into Action directed a team comprised of:

- David Jump, Ph.D., PE, William E. Koran, PE, and David Zankowsky of QuEST;
- Mark Stetz, PE, CMVP, of Stetz Consulting;
- Erik Kolderup, PE, LEED AP, of Kolderup Consulting; and
- Kevin Warren, PE, of Warren Energy Engineering.

The Research Into Action team was led by Jane S. Peters, Ph.D., and Marjorie McRae, Ph.D. Assisting Drs. Peters and McRae were Robert Scholl, Joe Van Clock, Mersiha Spahic, Anna Kim, Alexandra Dunn, Ph.D., and Kathleen Gygi, Ph.D.

For BPA, Todd Amundson, PE, directed the M&V protocol research and development activities. Mr. Amundson was working under the direction of Ryan Fedie, PE, and was assisted by BPA engineers. Mr. Amundson coordinated this work with protocol development work undertaken by the Regional Technical Forum. In addition, Mr. Amundson obtained feedback from regional stakeholders.

Kevin Warren is the primary author of this *End-Use Metering Absent Baseline Measurement: An M&V Application Protocol Guide*; team members reviewed and provided guidance.

2. Overview of Method

2.1. Description

The BPA *End-Use Metering Protocol* provides guidance to verify energy savings for energy conservation measures (ECMs) in equipment or end uses. These methods are useful when the savings for an ECM are too small to be resolved with whole-building or facility energy meters, or for stand-alone equipment as may be found in the commercial, industrial, and agricultural sectors. It may also be applied to some new construction ECMs affecting equipment or end uses. Verifying savings from ECMs that involve multiple pieces of equipment with interactions among multiple or complex energy flow paths is not a good application of the protocol.

This *Absent Baseline Application Guide* applies the *End-Use Metering Protocol* to the problem of verifying savings of energy-efficient equipment installed in situations where the baseline cannot be directly measured. For many energy efficiency measures, the baseline is not defined by the equipment or behaviors in place prior to the installation of the measure. Such situations include, but are not limited to, newly constructed facilities, major additions to an existing facility, or installation of efficient equipment that replaces equipment that had failed and reached the end of its useful life. This application guide has been written to illustrate how the methods in the *End-Use Metering Protocol* can be applied when the baseline cannot be measured.

Briefly, instead of using baseline measurements, the engineer must use information from sources such as Energy Code minimum efficiencies, Energy Code required features, and manufacturer data presenting equipment performance curves, characteristics, or tables. The methods to be used vary by whether the equipment draws constant load or variable load, and operates with a constant schedule or variable schedule.

Note that a modeling approach is a commonly used M&V approach for new construction projects. Modeling is not included in this application guide; the processes in the application guide are an alternative approach to modeling.

2.2. Applicability

Section 2.2 of the Regional Technical Forum's *Guidelines for the Development and Maintenance of RTF Savings Estimation Methods*[3] addresses baselines for energy-saving measures. Two primary baseline types are defined: *current practice* and *pre-conditions*. A current practice baseline is typical for appliance measures. New construction and major renovations that are covered by codes and standards use this baseline. Conversely, a *pre-conditions* baseline is used when the "measure-affected equipment or practice still has remaining useful life." According to the *RTF Guidelines*, "the use of the terms upgrade, replacement and conversion in describing a measure all indicate that savings for the measure are estimated using a *pre-conditions* baseline."

3 Hereinafter, *RTF Guidelines.*

This protocol is applicable to measures with *current practice* baselines, including the following situations:

- ➡ New building design and construction that incorporates high-performance features
- ➡ A major addition to an existing facility that incorporates high-performance features
- ➡ Energy-efficient equipment is installed to replace equipment that has failed (sometimes referred to as *replace-on-burnout*)

Section 2.2.1 of the *RTF Guidelines* describes current practice baselines. Of primary relevance to the types of medium to large projects that are typically subject to M&V is this passage:

> "As a general rule the RTF will use a baseline that is characterized by current market practice or the minimum requirements of applicable codes or standards, whichever is more efficient. Major renovations that are covered by codes and standards use this baseline."

The *End-Use Metering Protocol* defines the energy use characteristics of equipment or end uses according to their load and hours-of-use components, and whether they are constant or variable. Four load and hours-of-use categories are defined. This Guide is applicable to all four categories – equipment with: *constant load, timed schedule* (CLTS); *variable load, timed schedule* (VLTS); *constant load, variable schedule* (CLVS); and *variable load, variable schedule* (VLVS).

Normally, a single baseline is determined for a project and a single annual verified savings estimate is determined. However, in some jurisdictions, two baselines may be assigned to a project. Consider a measure that is expected to have a useful life of 15 years that replaces an existing unit that is 10 years old. When estimating the lifetime savings of the project, a *pre-condition* baseline is assumed for the first 5 years and a *current practice* baseline for the remaining 10 years.

2.3. Advantages of this Approach for Estimating Savings from Equipment-Absent Baseline Measurement

Use of the *End-Use Metering Protocol* has several advantages:

- ➡ The protocol enables verification of ECMs on specific equipment using data and information that was used to develop the savings estimates.
- ➡ When the resolution of the project's savings against the whole-building or meter baseline must be significant, this protocol is more advantageous over whole-building methods.
- ➡ Under *IPMVP Option A*,[4] the protocol allows for use of the abundant technical information from manufacturers, such as equipment performance curves, design and nameplate information, and so on.
- ➡ Many of the measurements required by the protocol can be achieved in a relatively short time period.

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4 *International Performance Measurement and Verification Protocol*.

- The methods may be applied to more complicated systems, as long as their operational characteristics fall into the categories identified above.
- The methods allow uncertainty in the savings estimates to be quantified, should that be a project requirement.

These advantages apply equally to projects where the baseline can be directly measured and to the projects that are the subject of this application guide – projects where direct measurement of the baseline is not possible.

For new construction projects, the primary alternative to this method is to use computer simulation modeling. To use computer simulation modeling as an M&V method, the models must be calibrated in accordance with the applicable protocol, a process that requires time and effort. The calibration process is not perfect and some uncertainty and potential for error remains. Also, because actual building data from the occupied state is required, it will typically take at least a year to collect utility bill information sufficient to calibrate the models. This may introduce a delay into the incentive payment process.

2.4. Disadvantages of this Approach for Estimating Savings from Equipment-Absent Baseline Measurement

The *End-Use Metering Protocol* is not appropriate for multiple ECMs installed throughout a building, where a whole-building approach is more appropriate. The methods described in the *End-Use Metering Protocol* do not account for energy interactions, such as heating savings from a lighting retrofit project. Projects with highly randomized load and schedule characteristics may not be appropriate for the methodology.

3. Algorithms

3.1. Basic Procedure

The basic procedure for applying the method is described in the *End-Use Metering Protocol*. Below, it is customized for projects where the baseline cannot be directly measured. Characterizing the equipment's energy use properties into constant or variable load and hours-of-use facilitates development of the M&V Plan for each project. The baseline must also be defined. The fundamental procedure is as follows (see Figure 3.1 for a flow chart of this procedure).

1. Identify which of the four categories described in the *End-Use Metering Protocol* and summarized in Section 2.2 best represents the anticipated post-installation equipment's load and hours-of-use characteristics.

2. Determine the baseline for the project.

3. By comparing the ECM to the baseline, determine the impact the ECM will have on the equipment's load or hours-of-use. Determine if it will change the load or hours-of use, or change them from constant to variable.

4. Identify which of the four categories described in the *End-Use Metering Protocol* and summarized in Section 2.2 best represents the equipment's baseline load and hours-of-use characteristics.

5. Identify the most appropriate equations to be used to determine energy savings.

6. Determine the relationships between load and hours-of-use terms in the energy savings equation and other parameters (i.e., temperature, air or water flow, pressure, and so on).

7. Identify and collect the required data in the post-implementation period.

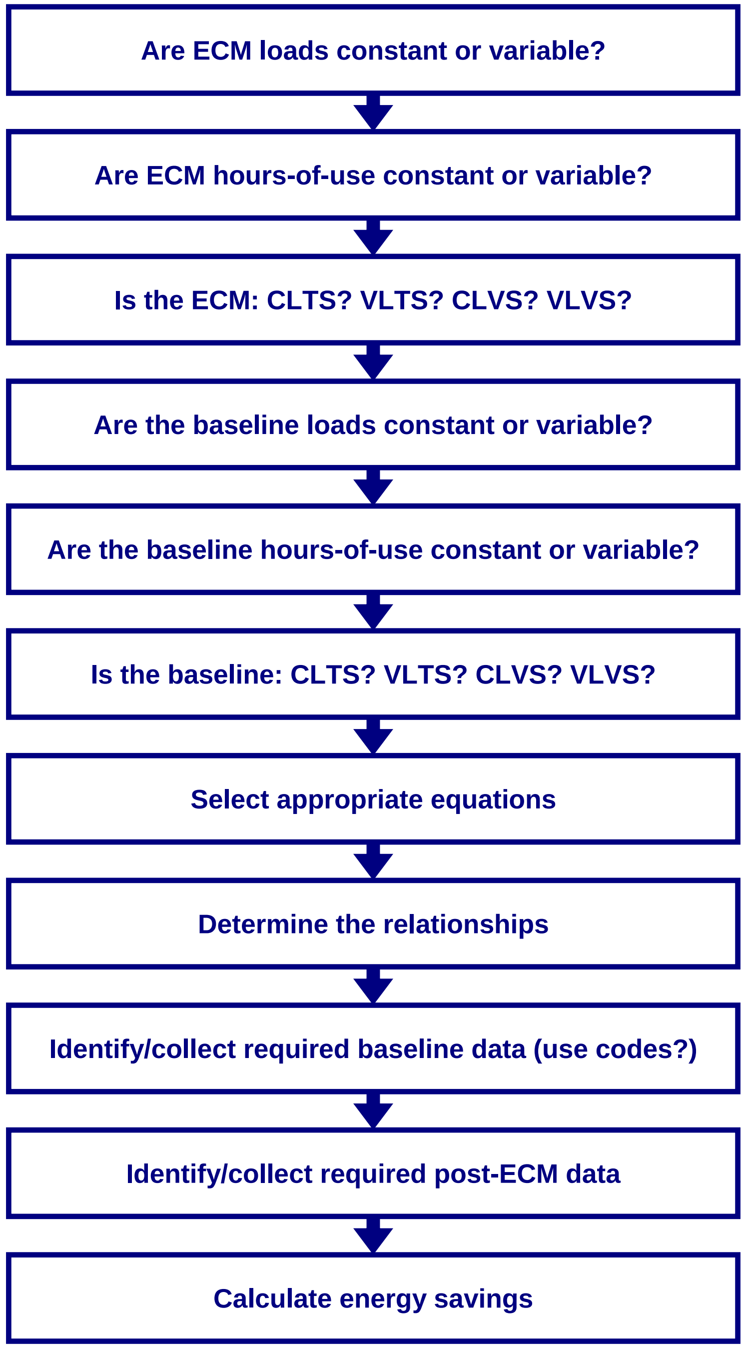
8. Identify and collect the required baseline data (from sources such as codes, rather than from metering).

9. Calculate energy savings using the equations in the *End-Use Metering Protocol*.

The *End-Use Metering Protocol* provides guidance on measuring and estimating parameters. Under *IPMVP Option A*, either the load or the hours-of-use must be measured and the other can be estimated. Option A does <u>not</u> allow both load and hours-of-use parameters (including all of their sub-parameters) to be estimated – key parameters must be identified and <u>measured</u>. Under *IPMVP Option B*, <u>both</u> load and hours-of-use parameters must be measured.

Under Option A, key parameters for measurement are identified and the other parameters to the savings calculation may be estimated based on reliable sources. The key parameters to be measured are normally the most uncertain or unknown parameters. Reliable sources include past measurements, manufacturer specifications and performance curves, lighting wattage tables, and so on. When applying this protocol to new construction ECMs where there is no baseline equipment for measurement, the relevant building code or standard may be used to define estimated parameters.

Figure 3-1: Customized Basic Procedure Flowchart



Refer to the *End-Use Metering Protocol* for additional guidance on selecting the duration of metering and extrapolating results to an annual basis.

3.2. Equations

The *End-Use Metering Protocol* states that it is often not necessary to repeat baseline data collection activities in the post-implementation period. One parameter (either load or hours) is often not affected by the ECM. In the *End-Use Metering Protocol*, the recommended approach is to measure the unchanged parameter in the baseline period and apply it to both baseline and post-installation scenarios. The same logic can be applied to measures covered by this Guide, except that the unchanged parameter will have to be measured in the post-implementation period.

Tables 2 through 5 of the *End-Use Metering Protocol* contain energy savings equations that may be used for each combination of load and schedule category. Within each table, the impact of the ECM on the load, hours-of-use, or both, determines the potential energy savings equations that may be used. These equations apply equally well to projects of the type addressed by this Application Guide.

3.3. Uncertainty

The guidance provided in the *End-Use Metering Protocol* should be followed. Where baseline values are fully determined from code, the value is known with statistical certainty. However, often the baseline load or schedule is only partly known with certainty.

For example, the baseline load for a new construction lighting project is typically determined by:

- *kW = lighting density (watts/sq.ft.) x floor area (sq.ft.)*

The lighting density is known with statistical certainty, since it is taken from a table in the applicable energy code. As long as the correct code version and the correct facility or space type are used, the lighting density value is known. There could be uncertainty around the estimate of floor area. The uncertainty for an equation where two variables are multiplied is:

- $x = a \cdot b\,;\ (\Delta x/x)^2 = (\Delta a/a)^2 + (\Delta b/b)^2$

Thus, if the one variable is known with certainty, the relative error in the product is equal to the relative error in the one variable.

4. Issues Specific to a New Construction Application of the End-Use Metering Protocol

4.1. Baseline

BPA Custom Project program rules define new construction savings relative to "code" standards without defining what those standards are. Table 4-1 of this Guide defines the default applicable code standard based on state-level building codes in effect as of August 2011.

Table 4-1: Building Energy Codes Applicable as of August 2011

Location	Applicable Building Energy Code Baseline
Idaho	IECC 2009 (effective January 1, 2011)
Montana	IECC 2009 or ASHRAE 90.1-2007; summarized in *Montana Commercial Building Energy Code* (July 2011)
Nevada	IECC 2009
Oregon	*Oregon Energy Efficiency Specialty Code 2010* (effective July 1, 2010); plus SEED Appendix L modeling requirements (effective October 1, 2010)
Washington	*Washington Non-Residential Energy Code 2009* (Prescriptive Path; beginning 4/1/11)
Seattle, WA	*Washington Non-Residential Energy Code 2009*; plus *Seattle Building Code* (Effective October 29, 2010)
Utah	IECC 2009
Wyoming	BPA requires ASHRAE 90.1-2007 for the Custom Project program in the place of MEC 1989 (the default state code)
Non-Building Applications	For custom applications, process loads, and non-building projects (e.g., refrigeration, agricultural pumping, industrial process), please consult with BPA for direction

When states update their non-residential building energy codes, the code in effect during the design phase shall prevail. Where local jurisdictions have energy codes more stringent than state codes, the local code establishes the baseline. The guiding principal when establishing a baseline is that the applicable code defines *what would have been built* in the absence of energy-efficient design.

A baseline must also be defined for measures which replace failed equipment or are installed in a new process in non-building applications. In such cases, there is typically no energy code that applies. The baseline should reflect the conditions that *would have occurred* in the absence of the project. For non-building applications, this is typically defined as the industry standard practice.

Industry standard practice can be difficult to define. Publications can be useful for determining the practices that are common for a particular industry or system. Note, however, that articles tend to focus on new or innovative approaches. The standard practice is less likely to be highlighted. The practices of the customer at other locations can be considered. However, the customer may consistently exceed standard practice. If the customer uses different practices in jurisdictions that have incentives for energy efficiency than in other jurisdictions, this presents a strong basis for the standard practice. The practices of the customer’s competitors can be considered, but this information can be difficult to obtain.

4.2. Post-Installation

Guidance on the data to be collected in the post-implementation period is provided in the *End-Use Metering Protocol*.

4.3. ASHRAE 90.1 Appendix G

Some new construction programs make use of *ASHRAE Standard 90.1 Appendix G* to define the baseline. Appendix G defines baseline HVAC system types based on the size of the building. For example, the baseline system type for a large (>150,000 sq.ft.) nonresidential building is a variable air volume fan system with reheat at the terminal boxes (VAVRH). The baseline system type may be a different type than the system actually installed in the building. If a high efficiency heat pump system was installed, and the baseline was defined as a VAVRH system, then the savings cannot be easily determined by the methods in the *End-Use Metering Protocol*. A modeling approach is generally required for a case where the entire system type is changed.

If Appendix G is not used to define the baseline, the baseline for the high efficiency heat pump ECM would be code-compliant heat pumps. For this case, the methods in the *End-Use Metering Protocol* can be used to determine the savings.

Appendix G also defines baseline characteristics for some parameters for which no minimum efficiency is specified in the main code. For example, the 2007 version specifies baseline pump power for systems with hot water pumps as 19 watts per GPM. Such values may provide a defensible baseline for a highly efficient hot water pumping and distribution system.

5. Minimum Reporting Requirements

5.1. Measurement and Verification Plan

5.1.1. Essential Elements of the Measurement and Verification Plan

Proper savings verification requires planning and preparation. The IPMVP lists several requirements for a fully-adherent M&V plan.[5] The *Absent Baseline Application Guide* describes methods to for verifying savings in equipment and end uses. This guide describes planning requirements, as well as specific measurement and analysis activities. Documenting in an M&V Plan how these requirements will be met is important so that others who subsequently become involved in the project can obtain a full understanding of the project's history and progress. The following are the essential items in documenting a savings verification plan.

- **Measurement Boundary:** Define the boundary around the equipment or end use within which the savings will be verified. This boundary can be around a specific piece of equipment, such as a pump and its motor, or a combination of equipment comprising a building subsystem, such as an air-handling system or chilled-water system.
- **Baseline Equipment and Conditions:** Document the end-use baseline systems, equipment configurations, and operational characteristics (operating practices or operation schedules that characterize its hours-of-use). This includes equipment inventories, sizes, types, and condition. Describe any significant problems with the equipment. .
- **Energy and Independent Variable Data:** Describe how equipment load is characterized and what additional parameters are required to characterize it. Describe its operating practices or operation schedules that characterize its hours-of-use. Include all energy data from spot measurements and short- or long-term monitoring from each source where data was collected. Define the baseline time period for the end use.
- **Reporting Period:** Describe the length of the reporting period and the activities that will be conducted, including data collection and sources.
- **Analysis Procedure:** Describe how the baseline and post-installation energy use or demand will be adjusted to a common set of conditions. Describe the procedures used to prepare the data. Describe the procedures used for analyzing the data and determining savings. Describe any extrapolations of energy use or savings beyond the reporting period. Describe how savings uncertainty (if required) will be estimated. Document all assumptions.
- **Option A Requirements:** For each non-key parameter, specify the basis for the estimated values used. Describe their source or sources. Describe the impact of any

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[5] *Chapter 5, IPMVP Volume I – 2010*.

significant variation in the values used and what otherwise would be measured on the calculated savings.

- **Savings Verification Reports:** Describe what results will be included in the savings reports. Describe what data and calculations will be provided. Describe when savings will be reported for the project. Indicate the reporting format to be used. See the section below regarding the *Savings Verification* Report for the minimum requirements.

5.1.2. M&V Plan Additional Elements

The IPMVP describes several other elements of a good M&V plan. These items are good practice in general, but not necessary for every project. Many of them are provided here for reference and consideration for inclusion in M&V Plans written under this guide.

- **Energy Prices:** Document the relevant energy prices to be used to value the savings. This can be a blended electric rate or a schedule of rates based on time-of-use. Note that the latter will add significant complexity to the calculations.
- **Measurement Instrument Specifications:** Document the instruments used to obtain the data used in the calculations, including their rated accuracy and range. Identify the last instrument calibration date.
- **Budget:** Estimate the budget required for the savings verification activity. Estimate labor and material (e.g., meters and instruments, associated safety equipment, etc.) costs and provide an approximate schedule for when activities will occur.
- **Quality Assurance:** Describe any quality assurance activities that will be conducted as part of this M&V project. This may include how data is validated, how *IPMVP Option A* estimates are checked, identifying other parties who will review the work, and so on.

5.1.3. Documentation for BPA Database

The documentation should also include the following information to support review and inclusion of the project and measure in the BPA *Energy Efficiency Central* database (*EE Central*)*:*

- Utility name
- Utility program
- Sector (commercial/industrial/residential)
- Existing building or new construction
- Site address (this will be used to establish the climate zone)
- Building type (examples: office, school, hospital)
- Building size, square feet

- Affected end uses (examples: HVAC, interior lights, exterior lights, receptacle plugs, DHW)
- Affected system (examples under HVAC: cooling plant, heating plant, HVAC fans, terminal units, controls)
- Affected equipment type (examples under cooling plant: chiller, packaged unit, cooling tower, pumps)
- Measure type (broad category)
- Measure name (specific category)

5.2. Savings Verification Report

5.2.1. General Verification Report Requirements Based on IPMVP

After the M&V calculations have been completed, the savings and actual M&V process used need to be documented. Per the IPMVP, the *Savings Verification Report* should follow the savings verification report requirements described in the project's M&V Plan. Any deviations from the M&V Plan must be clearly described. If the M&V method followed the M&V Plan, then the information in the M&V Plan does not need to be repeated, but can just reference the Plan. However, deviations from the planned method, measurement boundary, baseline characteristics, etc. necessitate new descriptions.

IPMVP Chapter 6, M&V Reporting, generally requires the following:

- Report both energy and cost savings.
- Report the data relevant to the reporting period, including the measurement period and the associated energy data and independent variables. Any changes to the observed data must be described and justified.
- Describe any non-routine baseline adjustments, including the details of how the adjustments were calculated.
- Report the energy prices or rates used in the cost-savings calculations.

In addition, actual data for baseline and post-period energy use should both be reported.

5.2.2. Additional Savings Verification Report Requirements

Load and Schedule Relationships

In the basic procedure for the *End-Use Metering Protocol*, one of the numbered items states, "Determine the relationships between load and hours-of-use terms in the energy savings equation and other parameters, such as temperature, air or water flow, pressure, and so on." This includes the relationships of daytypes and seasons to load and hours-of-use.

These relationships are important for all protocols, not just the *End-Use Metering Protocol*. In general, if the power or energy varies with respect to ambient temperature or another independent variable, then a relationship (e.g., regression) must be developed. Schedule variations require similar considerations.

The energy modeling protocol is obviously built on these relationships, and energy indexing uses the ratio between energy and some independent driving variable – another relationship. Similarly, spreadsheet-based engineering calculations should use relationships (also described as correlations) to describe the load.

The savings verification report should clearly define loads and schedules, and their relationship to other variables:

- ➡ **For a constant load**, the load value and units should be provided, as well as how the load value was obtained. If any proxies are used to define the load, the proxies should be justified and their development described.
- ➡ **For variable load**, the load frequency distribution should be provided, along with a description of how it was obtained. For loads that can be any value, they should generally be grouped into 5 to 10 bins, but this is dependent upon how much the load varies. For example, if the load varies from 0% to 100%, 10 bins might be appropriate, but if the load only varies from 80% to 100%, then 2 to 4 bins might be appropriate.
- ➡ **For a timed schedule**, report the source for the schedule and the total annual hours.
- ➡ **For a variable schedule**, report the source for the estimate of the hours during the measurement period and the total annual hours.

Variable load information, energy models, and load correlations for engineering calculations are all similar and should be shown graphically in an x-y (scatter chart), as well as an equation or table. Load frequency distributions should be shown in both a bar chart and a table.

Savings Verification Report Information

The report should include the following information. It may be organized in this order with a separate section for each of these items, or in another order or organization that makes sense for a particular program or project. However it is reported, all of this information should be included in most cases:

1. The data for the baseline period, including the time period, monitoring intervals, and data points should be described.
2. The load and schedule for the baseline period, and any relationships associated with variable loads or schedules, should be clearly defined.
3. The impact of the ECM on the load or hours-of-use in the reporting period should be described.
4. The data for the reporting period, including the time period, monitoring intervals, and data points should be described.

5. The load and schedule, and any relationships associated with variable loads or schedules, should be clearly defined for the reporting period.
6. The equations used to estimate baseline consumption, reporting period consumption, and savings should be listed and explained.
7. Report consumption (and where relevant, demand), as well as savings, since this facilitates review and reasonableness checks.
8. As required by IPMVP, report the energy prices or rates used in the cost savings calculations.
9. Also, as required by IPMVP, report both energy and cost savings.
10. Provide verification of potential to generate savings.

Post Installation Verification of Potential to Generate Savings

IPMVP Section 4.3 requires that, "After the ECM is installed, inspect the installed equipment and revised operating procedures to ensure that they conform to the design intent of the ECM." Therefore, an IPMVP-adherent process requires evidence that the efficiency measures have the potential to generate savings. BPA may require short-term monitoring, spot measurements, production data, or other forms of verification to confirm potential.

Verification includes notation of any changes to the project subsequent to the M&V plan. If the project changed, the energy and demand savings should be recalculated based on as-installed conditions. Data and analysis from metering performed before or after installation should be included with the calculations.

In general, verification of potential to generate savings can take either of two forms:

- ➡ Installation verification
- ➡ Operational verification

Installation Verification

Installation verification is the less rigorous of the two verification methods. It demonstrates the measures were installed as planned. This demonstration may vary by measure. Project developers are required to describe the evidence and documentation they plan to provide to demonstrate that the measures were installed, and this evidence and documentation belongs in the savings verification report.

Examples of installation verification include:

- ➡ Photographs of new equipment
- ➡ Photographs of new control set-points
- ➡ Screen captures from EMCS

- ➡ Invoices from service contractors (invoices should not be the sole form of evidence, but may supplement other verification documentation).

Operational Verification

*Operational verificati*on demonstrates that in the post-installation period, the system is operating (or not operating) as modeled in the calculations. It is based on visualization of *operational* data (as opposed to *energy* data) collected during one or more site visits after the measures have been installed.

Operational verification is in addition to installation verification and documentation should include the same types of evidence as for installation verification. In addition, the data logging, control system trending, or functional tests used to establish baseline shall be repeated to demonstrate that operations have been improved. Documentation of the commissioning of the new systems or equipment can be used for operational verification.

If the collected post-installation data, test results, and/or commissioning indicate less than predicted performance, or that the measures were not installed as assumed in the savings calculations (for example, due to incorrect or partial installation, or other circumstance), either:

- ➡ Take action to help the customer fully install the measure properly and then re-verify it using these procedures; or
- ➡ Use the same calculation methodology with the post-installation data to calculate a revised measure savings estimate.

Choice of Verification Method

Common, well-known measures, measures with low expected savings, and measures whose savings estimates have considerable certainty, may need only installation verification. Measures with large savings and measures with less certain savings (whose savings can vary greatly dependent upon application) typically require operational verification.

Thus, there is no hard-and-fast rule for this choice. The analyst should recommend a verification method and the evidence expected to be presented for verification when submitting calculations or simulations. The final choice of verification method and evidence will be made by the reviewer.

6. Examples

6.1. Example 1 – New Construction Lighting

A new wing is being added to a building. The design team chooses to install high efficiency lighting. The electrical load of the installed lighting is less than the maximum lighting load allowed by local code. The lighting will be controlled by manual switches. An Option A approach will be used. The following outlines the M&V activities for this project.

a. Baseline
   i. *Load and Schedule Category*: CLVS (new construction)
   ii. *Measurements:* None. Record the floor area of the expansion from the architectural drawings for the project. Determine the baseline lighting density from the local energy code.

b. Post-Installation
   i. *Load and Schedule Category:* CLVS (new construction)
   ii. *Post-Installation Measurements*: Light loggers on a sample of fixtures for one month (annual hours based on extrapolation of hours of operation for all weekdays, weekends, and holidays). Verify the type and quantity of installed fixtures. The fixture wattage (load) may be estimated based on a lighting wattage table

The correct savings formula is selected from the *End-Use Metering Protocol*. In this case, for a CLVS project where the ECM has an impact on the load, but not the hours, savings is calculated by:

- $kWh_{saved} = \sum_i \left[(kW_{base,i} - kW_{post,i}) \cdot HRS_{post,i} \right]$

The baseline load for a new construction lighting project is determined by:

- kW_{base} = *lighting density (watts/sq.ft.) x floor area (sq.ft.)*

Lighting density can be determined based on the floor area and type of the facility as a whole, or based on the area and type of each space within the building. Guidance on use of *whole-building* or *space-by-space* methods is provided in the code.

The post-installation lighting load is determined by:

- $kW_{post} = \Sigma_i$ *(watts/fixture*$_i$ *x fixture quantity*$_{,i}$*)*

  where: i = each fixture type installed

6.2. Example 2 – Chiller Replacing a Failed Chiller

A facility has two chillers, but one is incapable of meeting the entire cooling load of the facility and functions as a backup only. The main chiller runs year-round to meet the cooling load of the facility. Some of the facility's air handlers run continuously, so there is no time-of-day scheduling of the chiller. An outside air lockout is used to disable the chilled water pumps and chiller when the outside air temperature is less than 55°. The main chiller is old and suffers a major failure. The site must install a new chiller. They elect to install a chiller that is more efficient than is required by the local energy code. An Option A approach will be used. The following outlines the M&V activities for this project.

a. Baseline
   i. *Load and Schedule Category*: VLTS (new construction)
   ii. *Measurements*: None. Determine the baseline chiller efficiency from the local energy code.

b. Post-Installation
   i. *Load and Schedule Category*: VLTS (new construction)
   ii. *Post-Installation Measurements*: Cooling plant load is monitored for several months by measuring chilled water GPM, chilled water supply temperature, and chilled water return temperature. Note that in some facilities, this data is available from existing energy management systems or industrial SCADA systems. A relationship between ambient dry-bulb temperature and cooling load is determined.

The correct savings formula is selected from the *End-Use Metering Protocol*. This case is a VLTS project where the ECM has an impact on the load but not the hours. The efficiency of the chiller is affected but the cooling load that is served is not affected. The savings is calculated by:

- $$kWh_{saved} = \sum_i \left[\left(Eff_{base,i} \cdot HRS_{post,i} - Eff_{post,i} \cdot HRS_{post,i} \right) \cdot Q_{post,i} \right]$$

where: $HRS_{post,\, i}$ = hours in ambient temperature bins as determined from typical weather files. A continuous schedule is used, but only hours above 55° F dry-bulb are included.

$Eff_{base,\, i}$ = minimum chiller efficiency required by code

$Eff_{post,\, i}$ = chiller efficiency at each temperature bin, as determined from a performance curve provided by the manufacturer

$Q_{post,\, i}$ = average cooling load at each temperature bin as determined from the post-installation metering of cooling plant load

6.3. Example 3 – New Construction High Efficiency Pump

In a new construction scenario, a design team chooses to design and install a more efficient pump motor than the local applicable codes require. The pump will be constant speed and operate a known number of hours per year. The savings will be based on the increased efficiency of the pump motor over that required by the building code. An Option A approach will be used. The following outlines the M&V activities for this project.

a. Baseline
   i. *Load and Schedule Category*: CLTS (new construction)
   ii. *Measurements*: None, however, record the local code's minimum pump motor efficiency.

b. Post-Installation
   i. *Load and Schedule Category*: CLTS (new construction)
   ii. *Post-Installation Measurements*: pump motor power (average of multiple measurements); motor status logging for one month (annual hours based on extrapolation of hours of operation for all weekdays, weekends, and holidays)

c. The known baseline value is the efficiency of the motor. The baseline kW is determined assuming that the motor load (brake horsepower) is the same as in the post-installation case.

   - $kWh_{base} = \left(Eff_{base} / Eff_{post} - 1\right) \cdot kW_{post}$

d. Savings calculated by:

   - $kWh_{saved} = \left(kW_{base(code)} - kW_{post}\right) \cdot HRS_{post}$

7. References and Resources

ASHRAE. 2002. *ASHRAE Guideline 14-2002 – Measurement of Energy and Demand Savings*. Atlanta, Ga.: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Purchase at: *http://www.techstreet.com/cgi-bin/detail?product_id=1645226.*

ASHRAE. 2010. *ASHRAE Standard 55-2010 – Thermal Environmental Conditions for Human Occupancy*. Atlanta, Ga.: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Purchase at: *http://www.techstreet.com/standards/ashrae/55_2010?product_id=1741646.*

ASHRAE. 2010. *ASHRAE Standard 62.1-2010 – Ventilation for Acceptable Indoor Air Quality*. Atlanta, Ga.: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Purchase at: *http://www.techstreet.com/standards/ashrae/62_1_2010?product_id=1720986.*

ASHRAE. 2010. *ASHRAE Standard 90.1-2010 – Energy Standard for Buildings Except Low-Rise Residential Buildings*. Atlanta, Ga.: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Purchase at: *http://www.techstreet.com/standards/ashrae/90_1_2010_i_p_?product_id=1739526.*

ICC. 2009. *2009 International Energy Conservation Code.* Washington D.C.: International Code Council.

Purchase at: *http://www.iccsafe.org/Store/Pages/Product.aspx?id=8780P09_PD-X-IC-P-2009-000014*.

IPMVP. 2010. *International Performance Measurement and Verification Protocol Volume 1: Concepts and Options for Determining Energy and Water Savings*. EVO 10000 – 1:2010. Washington, D.C.: Efficiency Valuation Organization.

Available at: *http://www.evo-world.org/index.php?option=com_form&form_id=38*.

IPMVP. 2006. *International Performance Measurement and Verification Protocol Volume III: Applications, I - Concepts and Practices for Determining Energy Savings in New Construction*. EVO 30000 – 1:2006. Washington, D.C.: Efficiency Valuation Organization.

Available at: *http://www.evo-world.org/index.php?option=com_form&form_id=13*.

Oregon Building Codes Division. 2010. *2010 Oregon Energy Efficiency Specialty Code.* Salem, Ore.: Oregon Department of Consumer & Business Services, Building Codes Division.

Available at: *http://ecodes.biz/ecodes_support/free_resources/Oregon/10_Energy/10_OREnergy_main.html.*

Regional Technical Forum. 2011. *Guidelines for the Development and Maintenance of RTF Savings Estimation Method*. Portland, Ore.: Northwest Power & Conservation Council. Available at: *http://www.nwcouncil.org/energy/rtf/subcommittees/deemed/Guidelines%20for%20RTF%20Savings%20Estimation%20Methods%20(Release%206-1-11).pdf*.

Washington State Building Code Council. 2011. *Washington State Energy Code, 2009 Edition.* 2nd Edition. Olympia, Wash.: Washington Association of Building Officials. Available at: *https://fortress.wa.gov/ga/apps/sbcc/Page.aspx?nid=14.*

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