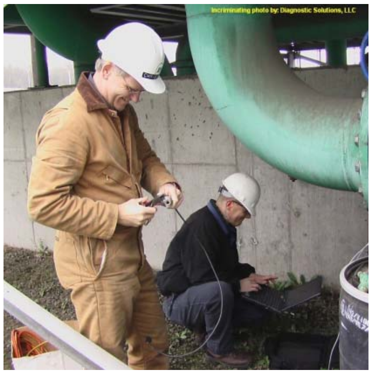


Verification by Energy Use Indexing Protocol

May 2012

Verification by Energy Use Indexing Protocol

Version 1.0

May 2012

Prepared for

Bonneville Power Administration

Prepared by

Research Into Action, Inc.

Quantum Energy Services & Technologies, Inc. (QuEST)

Stetz Consulting, LLC

Kolderup Consulting

Warren Energy Engineering, LLC

Left Fork Energy, Inc.

Schiller Consulting, Inc.

Contract Number 00044680

Table of Contents

1. Introduction

1.1. Purpose

This document presents a *Verification by Energy Use Indexing Protocol*[1] as a complement to the Measurement and Verification (M&V) protocols used by the Bonneville Power Administration (BPA). The *Verification by Energy Use Indexing Protocol* assists the engineer in normalizing one or more independent variables that systematically affect energy use to prevent non-program changes from confounding savings estimates. For example, the method is applicable when energy use is a function of gallons of water pumped or, in an industrial situation, the number of widgets produced. This protocol is a simple application BPA's *Verification by Energy Modeling Protocol.*[2] Savings can be large or small, but in most applications to multiple measures, the savings should not be interactive. The protocol is adherent with *IPMVP Options B* and *C*.

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 8 of this protocol 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;
- Warren Energy Engineering, LLC, the firm of Kevin Warren, PE;
- Schiller Consulting, Inc., the firm of Steven Schiller, PE; and

---

1 Hereinafter, *Energy Use Indexing Protocol.*

2 Hereinafter, *Energy Modeling Protocol.*

- 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.

William Koran is the primary author of this *Verification by Energy Use Indexing Protocol*; team members reviewed and provided guidance.

2. Overview of Method

2.1. Description

Routine changes in a building's operation or production variables can require normalizing to prevent non-program changes from confounding savings estimates. A common method to provide such normalizing is through the creation of some form of energy use index. This method estimates savings by observing changes in efficiency over time, as determined by energy use on a per-unit basis.

Reporting period savings are calculated using **Equation 1** in *Chapter 3, Algorithms*. Annual savings are calculated by multiplying the *net annual energy use* by the *calculated percentage savings*.

The most common index for commercial facilities may be energy use per square foot, per year, but other normalizing variables may be appropriate. Examples include weather (e.g., degree-days) and occupancy (e.g., hotel-room occupancy rates). Industrial facilities may often use indices related to their process, such as energy use per pound of manufactured output, per widget produced, or per gallon of fluid pumped. The time interval used for comparison may also vary depending upon the application.

2.2. Applicability

This method is applicable when the energy use affected by the efficiency measure is proportional to one or more independent variables. For example, this method may be used in industrial situations where energy use is a function of widgets produced. The method may not be applicable when energy use is significantly dependent on uncontrollable or relatively random variables, such as quality of raw materials received.

In contrast, variables must be measurable and correlated to energy for this method to be valid. It is essential that the impacts of different variables on energy use are well understood, at least on an empirical basis, and that all important non-program variables can be adequately controlled for measurement or can be normalized for this method to be used effectively. The importance of the possible independent variables should be evaluated using standard statistical methods, such as the computation of the *t-statistic* and *p-value*.

2.3. Advantages of this Protocol

Verification by energy use indexing is easily understood, at least for certain applications where factory managers or M&V professionals understand the variable(s) that drive energy use. Therefore, it meets the *International Performance Measurement and Verification Protocol* (IPMVP) requirement for a method to be transparent. If the parameters used for the indices continue to be measured over time, then the method can also be used for performance tracking.

The *Energy Use Indexing Protocol* may use simple linear regression. Since the Energy Use Index is simply a ratio, it includes the implicit assumption that energy use is linearly proportional to the normalizing variable. Therefore, it often lends itself to a visual representation of the savings in the form of a simple x-y scatter chart. As stated above, each parameter in the index – *kWh/units* – is either a total or an average aggregated over a period of time. In many cases, this will mean that there have been multiple measurements of kWh and multiple measurements of units. To represent the savings in a scatter chart, these measurements must occur in pairs occurring at the same time, with each pair consisting of one measurement of kWh and one measurement of units. Then a scatter chart could be created with the normalizing units on the x-axis and kWh on the y-axis.

Since this protocol is based on regression methods, it has significant related history and common use. For example, energy use has often been normalized by heating or cooling degree-days. This is an example of energy-use indexing. Other weather-related indices are similar.

This protocol can be somewhat distinct from regression methods in a specific circumstance, and in that case, indexing is a clearer, more transparent approach. *Chapter 7, Example* demonstrates this: regression requires that the independent and dependent variables be measured in concurrent pairs. If only a single point is needed to establish the slope, then the index is easily established and there is no need for a longer term of measurement for M&V. A longer baseline monitoring period may be needed to establish the run-time of equipment, for an annual extrapolation as part of energy savings forecast (ex ante estimate), but it is not needed to establish the index. A single, one-time measurement of the independent and dependent variable may be all that is needed in the case of constant-load equipment.

2.4. Disadvantages of this Protocol

There are several possible disadvantages. A possible issue that may preclude the use of this protocol is that the independent variable(s) needed for the indices may be proprietary and/or confidential. *If the independent variable(s) driving energy use cannot be measured or obtained, this protocol cannot be used*. This is an issue with most protocols. Note that the IPMVP states that:

> "Clear definitions of terminology and heavy emphasis on consistent, transparent methods are the core precepts of the IPMVP." [3]

It is not possible to use just the pre-post difference in the driving variable as a means of handling proprietary data. Without the baseline index, it would not be possible to determine the expected energy use as a result of the change in the driving variable.

Also, since this is, at its core, a regression-based method, independent variables that are not accounted for in the regression may introduce error or uncertainty. If the energy use is not a strong function of the independent variable(s), or if the random variation in energy use ("scatter" in the x-y chart) is significant relative to the correlation of the variables, then the protocol may

3 Letter of Introduction to the IPMVP, John Stephen Kromer, Chair of the Board of the Efficiency Valuation Organization, April 2007.

produce savings estimates that have high uncertainty. Ways to reduce uncertainty are discussed in the *Uncertainty* chapter in this protocol.

Another issue is that the regression must be approximately linear over the range of interest. The *range of interest* is the range of the independent variable(s) affected by the measure. If the regression has a change point (for example, if there is a limit on the value of the energy use for values of the independent variable beyond a certain threshold), then energy indexing cannot be used unless energy use is not expected to change as a result of the measure for values of the independent variable beyond the threshold.

For example, HVAC energy use may be proportional to cooling degree-days. However, when cooling degree-days decrease to zero and below, the HVAC energy use may not continue to decrease – fan energy may remain constant below that point. To use energy indexing under these conditions, exclusions must be applied so that the calculations only include the range of independent variable(s) for which energy use is dependent, and it is easier to do that with other methods.

Another point regarding the treatment of energy indexing as a regression: *It only estimates savings for a change in the regression slope*, because the energy indexing approach implicitly assumes that the y-intercept is the same for the pre and post cases, typically zero. Therefore, this protocol cannot be used for measures where the regression slope does not change, since that would not result in any change to the index.

Finally, if there is more than one continuous independent (normalizing) variable, this method will be much less transparent – in this case, a clearer regression method should be used. If there is one continuous variable and one or more categorical variables, an energy use indexing method may still be appropriate. *Categorical variables* are variables that have discrete values and are not continuous. For example, *daytype* could be a categorical variable. Creating temperature bins makes a categorical variable out of a continuous variable (see the following chapter).

3. Algorithms

3.1. Basic Procedure

The appropriate equation is:

- **Equation 1:** $actual\ savings\ (kWh) = ((kWh/units)_{base} - (kWh/units)_{post}) \times units$

  where:

  - *Actual savings* refers to savings occurring during the reporting period.
  - *Units* is the normalizing variable, such as square feet, widgets produced, etc. The number of units must be over the same time period as the corresponding energy use.
  - Each parameter (kWh, units) in the ratio, kWh/units, is either a total or an average aggregated over a period of time. Alternatively, the ratio may be the slope of a regression with units as the independent variable and kWh (or other energy use measure) as the dependent variable.

3.2. Equations

The predecessor to this protocol[4] showed the savings to be calculated as follows:

- **Equation 2:** $percentage\ savings = ((kWh/units)_{base} - (kWh/units)_{post}) \div (kWh/units)_{base}$
- **Equation 3:** $actual\ savings\ (kWh) = percent\ savings \times kWh_{base}$

The two equations can be combined as follows:

- **Equation 4:** $actual\ savings = ((kWh/units)_{base} - (kWh/units)_{post}) \div (kWh/units)_{base} \times kWh_{base}$

Which can be further simplified to:

- **Equation 5:** $actual\ savings\ (kWh) = ((kWh/units)_{base} - (kWh/units)_{post}) \times units_{base}$

The new version of this protocol (**Equation 1**) uses *units* rather than $units_{base}$, as was used in **Equation 5** of the prior version of this protocol:

- **Equation 1:** $actual\ savings\ (kWh) = ((kWh/units)_{base} - (kWh/units)_{post})$ $\boldsymbol{\times\ units}$
- **Equation 5:** $actual\ savings\ (kWh) = ((kWh/units)_{base} - (kWh/units)_{post})$ $\boldsymbol{\times\ units_{base}}$

---

[4] Harding, S, F. Gordon, and M. Kennedy. *Site Specific Verification Guidelines*, Section "Verification of Energy Indexing," pages 31–34.

The choice of what to use for the units multiplier in **Equation 1** is dependent upon whether the project or program uses the *avoided energy use* or the *normalized savings* approach to estimate savings.

Sections 4.6.1 and *4.6.2* of *Volume I* of *IPMVP 2010* discusses two types of savings: *avoided energy use* and *normalized savings*.

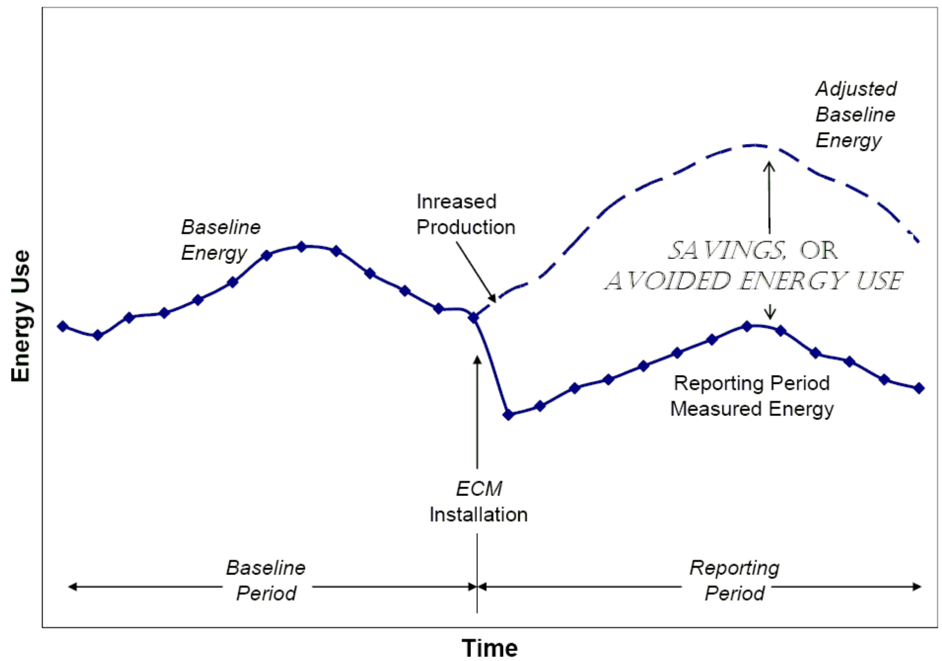
- **Avoided Energy Use:** the Reporting-Period Basis type of savings is provided by using $units_{post}$ for the *units* multiplier in **Equation 1**.
- **Normalized Savings (Fixed Conditions Basis Savings):** adjusts both baseline and post periods to some fixed conditions. Such fixed conditions could be the baseline conditions, as indicated by the prior version of this protocol, but need not be.

In *Section 4.1*, *IPMVP 2010* describes how the baseline is adjusted to post conditions using the *avoided energy use* approach:

> "To properly document the impact of the ECM, its energy effect must be separated from the energy effect of the increased production. The 'baseline energy' use pattern before ECM installation was studied to determine the relationship between energy use and production. Following ECM installation, this baseline relationship was used to estimate how much energy the plant would have used each month if there had been no ECM (called the "adjusted-baseline energy"). The saving, or 'avoided energy use' is the difference between the adjusted-baseline energy and the energy that was actually metered during the reporting period."

This is shown in Figure 3-1, also from *IPMVP Volume I*, Section 4.1:

Figure 3-1: Example Energy History



Consider the following hypothetical example of the *avoided energy use* approach (Table 3-1):

Table 3-1: Example Using Avoided Energy Use Approach

	Base	Post	Percent Savings
kWh	10,000	8,000	
Units	400	500	
kWh/units	25	16	36%

Using **Equation 1,** the **Actual Savings** would be calculated as follows:

- Actual savings (kWh) = $((kWh/units)_{base} - (kWh/units)_{post}) \times units_{post}$
- Actual savings (kWh) = $(25 - 16) \times 500 = 4{,}500$

Using **Equation 2**, the **Percentage Savings** would be:

- Percentage savings (kWh) = $((kWh/units)_{base} - (kWh/units)_{post}) \div (kWh/units)_{base}$
- Percentage savings (kWh) = $(25 - 16) \div 25 = 36\%$

Using **Equation 3**, the **Actual Savings** would be:

- Actual savings (kWh) = $Percent\ savings \times kWh_{base}$
- Actual savings (kWh) = $36\% \times 10{,}000 = 3{,}600$

We can check **Equation 1** by taking the extra step to adjust the baseline to the post conditions and then calculating the savings:

Keeping the index (kWh/units) the same, the baseline kWh is adjusted to reflect the units produced in the post period (Table 3-2):

Table 3-2: Actual Savings Verified Through Baseline Adjustment Method

	Base	Post	Percent Savings
kWh	12,500	8,000	
Units	500	500	
kWh/units	25	16	36%

Now the savings can be directly calculated as *12,500 – 8,000 = 4,500 kWh*. This matches the value shown by **Equation 1**.

By using $units_{base}$ as the multiplier in **Equation 5**, the earlier version of this protocol essentially used the *normalized savings* approach as described by the *IPMVP* in *Section 4.6.2*, with the *Fixed Conditions Basis* being the baseline conditions:

> "Conditions other than those of the reporting period may be used as the basis for adjustment. The conditions may be those of the baseline period, some other arbitrary period, or a typical, average or 'normal' set of conditions. Adjustment to a fixed set of conditions reports a style of savings that

> could be called 'normalized savings' of the reporting period. In this method energy of the reporting period and possibly of the baseline period are adjusted from their actual conditions to the common fixed (or 'normal') set of conditions selected."

The typical *avoided energy use* approach is a subset of the *normalized savings* approach. The *normalized savings* approach adjusts both baseline and post to a *fixed set of conditions*. The *avoided energy use* approach uses the set of post conditions as the fixed set of conditions. In the prior version of the protocol, the fixed set of conditions was the set of baseline conditions, so the post period was adjusted to the baseline.

The *avoided energy* use style of savings is somewhat simpler, since it is a subset of the normalized savings approach. The post period represents reality; it is not modeled. The savings so estimated represent the true savings achieved over the post period, within the accuracy of the baseline model.

The *normalized savings* approach, does not estimate the actual savings achieved over the post period, but it has the benefit that the savings estimated can be directly compared with any ex ante savings estimates if the *fixed conditions* are the same as used in the ex ante estimates.

So, for estimates of actual savings, the *avoided energy use approach* is recommended if savings are to be estimated retrospectively, after a complete cycle of conditions – typically a year – has occurred in the post period. However, if typical or average savings are to be estimated (e.g., if savings for a year are to be forecast prior to obtaining a full year of post-implementation data, or if reimbursements or incentives are to be paid based on expected long-term savings), it may be appropriate to use a *normalized savings* approach.

4. Measurement and Monitoring

A baseline is established by determining a pre-measure *energy-use-per-unit*. This may be done with utility billing data and data on output, or another use index if the billing data provide sufficient resolution, or with submetering of the affected equipment and measurement or acquisition (from external sources) of the normalizing variable(s).

Measurements should be conducted for a sufficient period to capture a significant range of the independent variable(s). In a production environment, the consistency of production will determine this length of time. When weather is the independent variable, the season and climate will determine the length of time necessary. If seasonal variations in weather are minor, a relatively short time may be possible and still cover a wide range of conditions. If seasonal variations are significant, longer periods (up to a year) may be advisable.

This issue of "how much data is enough" is further discussed in *Chapter 5, Uncertainty*.

As discussed in *Section 2.4: Disadvantages of this Protocol*, development of the baseline should include a check to make sure that the index is fairly constant (the regression is linear) over the range of interest. This is simply done with an x-y scatter chart.

Often, depending upon the measurement frequency and the interval over which the energy use is aggregated, categorical variables may be important to consider and separate energy-use indices may be necessary for each value of a categorical variable.

For example, if a plant produces two types of widgets and the energy use per widget is not the same for each type, then separate indices will be needed. Each index could still use **Equation 1** to estimate the savings, and the total savings would be estimated by summing the results of **Equation 1** for each type of widget. A similar issue can arise if energy use differs by *daytype* (e.g., there are different energy-use rates on weekdays vs. weekends). Again, separate indices may be needed for each daytype. If the measurement interval is monthly, then there may be different numbers of weekdays and weekends in the month, even for months with the same number of days.

Measurements of energy use and the indexing variable(s) must cover the same time periods. As stated above, measurements should be conducted for a sufficient period to capture a significant range of the independent variable(s). Measurements should only be taken after careful consideration of the limitations of the instrument and the requirements for its proper use.

Installation criteria for accurate measurement, such as the need for a straight duct of a specific number of equivalent duct diameters for a flow measurement, may be important. Note that, even though an installation limitation may introduce the same bias to the pre and post periods, the fact that the bias is the same may not mean that the savings estimate is not biased. Whether or not there is a savings bias is dependent upon the type of bias (e.g., additive or multiplicative) and how the measurement is mathematically used.

For a thorough discussion of measurements, refer to *Section 7, Instrumentation and Data Management*, and *Annex A, Physical Measurements*, within *ASHRAE Guideline 14, Measurement of Energy and Demand Savings*.

5. Uncertainty

Uncertainty in savings estimates can be attributable to multiple sources, including *measurement uncertainty* and *index uncertainty*. Since the index is the slope of a regression, the modeling uncertainty in the regression slope is a contributor to index uncertainty.

Instruments for acquiring measurements should be of sufficient resolution and precision that the uncertainties in measurements are small relative to the regression uncertainty in the index. Note that random errors in measurements are absorbed as random error in regressions. Measurement bias due to measuring equipment error should be eliminated through calibration, and careful instrumentation design and installation should be used to minimize other measurement bias errors. Where possible, utility meters should be used for energy-use measurements. Utility meter data can be considered to have zero uncertainty for savings estimates.

Similarly, data from a nearby National Oceanic and Atmospheric Administration (NOAA) weather station should be used for weather measurements, but such measurements should be verified to be representative of the conditions at the treated building. NOAA sites are far less likely to have biases or inaccuracies due to solar effects and sensor calibration errors than site measurements.

Perhaps the most important issue in estimating savings uncertainty is the extrapolation of sub-annual estimates to an annual basis. The most important factor has been stated twice previously in this protocol:

- ➡ **Measurements should be conducted for a sufficient period to capture a significant range of the independent variable(s).**

Beyond that, no definitive criteria can be provided regarding the sufficiency of shorter-term data for annual extrapolation. *ASHRAE Research Project 1404-TRP, Measurement, Modeling, Analysis and Reporting Protocols for Short-term M&V of Whole Building Energy Performance*, due for completion in early 2012, seeks to provide some guidance.

A goal of any M&V plan should be to minimize uncertainty in the savings estimate. More specifically, the goal should be to make the uncertainty small relative to the savings. *ASHRAE Guideline 14-2002, Annex B* refers to this as the *Fractional Savings Uncertainty*.

As with all M&V protocols, the emphasis on accuracy needs to be balanced against the level of savings and cost. Parametric analyses may be exercised on the M&V methodology, or if measurement uncertainty is a minimum, then factors affecting regression uncertainty may be assessed to determine the amount of effort and cost needed to increase accuracy.

Generally, factors that affect regression modeling uncertainty include:

- ➡ Number of points used in the baseline regression
- ➡ Number of points in the post-installation period
- ➡ Number of significant independent variables included in the regression

Costs may be affected by increasing the length of time required to collect data or monitoring additional variables.

One way to reduce the fractional savings uncertainty is to use more data.

➡ **In general, the more data acquired and used in the index, the lower the uncertainty.**

Gathering data over a longer time period, and/or at more frequent intervals, will generally reduce the uncertainty. Note, though, that as data is gathered at more frequent intervals, this will increase serial autocorrelation – each reading becomes more significantly related to the prior reading. Uncertainty estimates must account for this autocorrelation.

Another way to reduce the fractional savings uncertainty is to include more relevant independent variables. The *t-statistic* and *p-value* should be used to check for the relevance of additional independent variables. Again:

➡ **If multiple continuous independent variables – the denominator in the index – are significant, a different protocol is probably warranted.**

However, the inclusion of additional categorical variables may also reduce uncertainty. Note that the categorical variables may be different in the baseline and post scenarios, and care should be taken to check their significance.

Refer to *ASHRAE Guideline 14-2002, Annex B: Determination of Savings Uncertainty* for a more detailed discussion of savings uncertainty.

6. Minimum Reporting Requirements

6.1. Measurement and Verification Plan

6.1.1. 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 *Energy Use Indexing Protocol* describes methods for verifying savings in equipment and end uses. This protocol describes planning requirements, as well as specific measurement and analysis activities in the baseline and in the post-installation periods. 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:** Identify the independent variables to be used in the analysis (consider how the equipment load is characterized and what additional parameters are required to characterize it). Describe the sources of the energy and independent variable data and the time interval at which they are monitored. Describe any needed corrections to the data. Define the start and duration of monitoring for both the baseline and post-installation periods. Define the analysis time interval (such as hourly or daily). Include all energy data from spot measurements and short- or long-term monitoring from each source where data was collected.
- **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

5 *Chapter 5, IPMVP Volume I – 2010.*

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 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.

6.1.2. 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 protocol.

- **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.

6.1.3. 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)

6.2. Savings Verification Report

6.2.1. 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.

6.2.2. Additional Savings Verification Report Requirements

Load and Schedule Relationships

In the basic procedure for the *Verification by Equipment or 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 verification 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.

7. Example

This example applies the protocol with the measurement boundary at the equipment level.

7.1. Overview

Company ABC operates an industry-leading aggregates and construction services company in the Willamette Valley, one of several they own and operate in the Pacific Northwest region. The equipment under study is the crusher water-supply pumps at the main pumping station. All the pumps are on one meter. Over the last year, energy use has totaled 887,200 kWh, with an average demand of 227.4 kW and a peak demand of 252.8 kW. There are no data available for the water demand at the crusher or the submeter data for each of the four pumps.

The conservation target process is the crusher supply-water pumps. Two vertical turbine pumps, one 125-hp and one 100-hp, draw water from a pond at a near continuous rate through underground piping to the crusher plant. The 125-hp and 100-hp pumps operate under manual on/off controls. The crusher plant is estimated to be about 800 feet from the pumping station. The crusher requires a relatively high-pressure supply and its current supply volume is inadequate, based on interviews with plant personnel.

This project was designed to reduce overall energy consumption at the main pump station and improved supply conditions at the crusher. To accomplish this, it was recommended that the pumping station be consolidated into one 75-hp energy-efficient pump (3,200 GPM / 75 TDH), optimized to deliver 3,200 gallons per minute. Existing delivery lines will be examined in an attempt to eliminate the leaks that have limited historic flows. Additionally, this measure includes the installation of two booster pumps located close to the required end uses. These pumps will help ensure that properly pressurized water is delivered to the wash stations. These include one 60-hp (1,200 GPM, 180 TDH, 80 psi) just beyond the manifold to supply the crusher screen and one 15-hp (400 GPM, 90 TDH, 40 psi) at the classifier location.

Actual installed equipment included:

- One (ea) new energy-efficient 75-hp Vertical Turbine pump
- Miscellaneous installation equipment, including conduit, wire, and mounting hardware
- Varying lengths of new stainless steel and PVC discharge pipe and fittings
- One (ea) new energy-efficient 15-hp in-line booster pump
- One (ea) new energy-efficient 60-hp booster pump

7.2. M&V Approach

Overall energy savings will be measured by comparing the energy use per unit (kWh/kilo-gallon) efficiency before and after the project. This is an energy indexing approach as described in this protocol.

The measurement and verification plan for this project will rely on two sets of data monitoring sessions – one to provide pre-project data on energy consumption and system flow rates and a second to develop the efficiency metric. Additional variables, including pressure and flow, were also monitored. This data helped verify the post-project operating conditions of the main pump station, crusher-screen booster pump, and classifier-screen booster pump.

7.2.1. M&V Option

An Option B system approach was used for the energy use associated with water provided by the pumping station.

The measurement and verification team chose an energy efficiency metric, or index (kWh/kgal) to determine the savings amount for a full year. The savings were determined on a *fixed conditions* basis and the fixed conditions were selected to be the historic flows at the crusher. Since historic flows at the crusher were not measured, the historic energy use of the pumping station, from the pump station electric meter, was used as a proxy variable. The baseline monitored data was used to correlate the pumping station energy use to flow.

7.2.2. Measurement Boundary

The measurement boundary includes all of the pumps and the electric meter is the measurement device. No other energy-using devices are on the meter.

7.2.3. Baseline Period

Baseline period data was collected to develop the baseline energy models. The baseline periods for each meter, their analysis time interval, and number of points are shown in Table 7-1.

Table 7-1: Baseline Period

Meter	From	To	Interval	Unit
Electricity	August 21, 2008 11:45 AM	August 27, 2008 8:45 PM	10 minutes	Amps

7.2.4. Post-Installation Modeling Period

After the new equipment was installed and operational, post-installation energy use and flow data was collected. Table 7-2 summarizes the post-installation monitoring period.

Table 7-2: Post-Installation Monitoring Period

Meter	From	To	Interval	Unit
Electricity	July 31, 2009 10:00 AM	August 18, 2009 1:40 PM	5 minutes	kW

7.3. Energy Indexing

The purpose of the baseline monitoring period was to establish the run-time of the pumps, so that the annual energy use could be estimated for the ex ante savings estimate. Pump performance testing was accomplished at the time of typical operating conditions. However, only a single pair of measurements was needed to establish the index for the purposes of M&V, as shown in Table 7-3:

Table 7-3: Baseline Energy Index

Pump	Operating kW	Operating Gallons per Minute	Operating Gallons per Hour	Energy Index: kWh per 1,000 Gallons
125-hp	70.4	1,200	72,000	
100-hp	55.0	750	45,000	
Total	**125.4**	**1,950**	**117,000**	**1.072**

This index was used in conjunction with the utility bills to establish the annual historic water use, which was the fixed conditions basis for the savings (Table 7-4):

Table 7-4: Annual Water Use

Month	kWh	Gallons Calculated	Energy Index: kWh per 1,000 Gallons
Nov-07	81,000	75,574,163	
Dec-07	69,680	65,012,440	
Jan-08	83,520	77,925,359	
Feb-08	70,000	65,311,005	
Mar-08	64,640	60,310,048	
Apr-08	69,400	64,751,196	
May-08	68,720	64,116,746	
Jun-08	81,960	76,469,856	
Jul-08	94,680	88,337,799	
Aug-08	58,080	54,189,474	
Sep-08	77,200	72,028,708	
Oct-08	68,320	63,743,541	
Total	**887,200**	**827,770,335**	**1.072**

7.3.1. Post-Installation Modeling

Again, just a single pair of measurements was needed to establish the post-installation index (Table 7-5).

Table 7-5: Post-Installation Energy Index

Pump	Operating kW	Operating Gallons per Minute	Operating Gallons per Hour	Energy Index: kWh per 1,000 Gallons
75-hp Pump Station	52.6	2,775	166,500	
Booster Pumps	41.8	2,775	166,500	
Total	**94.4**	**2,775**	**166,500**	**0.567**

7.4. Annual Savings

Savings were estimated by adjusting post-installation energy use to the historic conditions. This was done simply by multiplying the post-installation index times the baseline water use, in gallons (Table 7-6).

Table 7-6: Company ABC's Willamette Valley Plant Annual Energy Savings

Phase	Water Use: 1,000 gallons	Energy Use Index: kWh per 1,000 gallons	Energy Use: kWh
Baseline	827,770	1.072	887,200
Post	827,770	0.567	469,318
Savings		**0.505**	**417,882**

8. 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.*

Harding, S., F. Gordon, and M. Kennedy. 1992. *Site Specific Verification Guidelines*. Portland, Ore.: Bonneville Power Administration.

Available at: *http://www.osti.gov/energycitations/servlets/purl/5171979-iBVWcf/5171979.pdf.*

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*.

Bonneville Power Administration
DOE\BP-4353 • May 2012