B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Measurement & Verification (M&V) Protocol Selection Guide and Example M&V Plan

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Contract Number 00044680

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1. Introduction

1.1. Purpose

This *Measurement & Verification (M&V) Protocol Selection Guide and Example M&V Plan*[1] is designed to assist in two ways the M&V practitioner charged with estimating site-specific gross energy savings for custom projects. The guide first provides assistance in selecting the appropriate Bonneville Power Authority (BPA) or Regional Technical Forum (RTF) M&V protocol or guidance document, followed by assistance in designing an M&V plan. This *Protocol Selection Guide* is one of many documents produced by BPA to direct M&V activities. It 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 guide to use for a given energy efficiency project. It also provides an example M&V plan. The document *Glossary for M&V: Reference Guide* defines terms used in the collection of BPA M&V protocols and guides.

Chapter 2 of this guide presents a framework for selecting the appropriate protocol or guide to use for savings assurance and Chapter 3 presents an example M&V plan. Chapter 4 provides full citations (and web locations, where applicable) of documents referenced in this guide.

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
- 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;

[1] Hereinafter, *Protocol Selection Guide*.

- 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 *Measurement & Verification (M&V) Protocol Selection Guide and Example M&V Plan*; team members reviewed and provided guidance.

2. Protocol Selection Guidance

This *Protocol Selection Guide* is designed to assist the M&V practitioner charged with estimating site-specific gross energy savings for custom projects with selecting the appropriate BPA or RTF M&V protocol or guidance document. However, there can always be unique project characteristics or concerns identified by BPA or utility staff which, with the professional judgment of those conducting the M&V activities, could result in selection of a different protocol than suggested by the criteria given in this guide.

BPA developed the protocols described in this guide in 2010 and 2011. Concurrently, the RTF developed its *Guidelines for the Development and Maintenance of RTF Savings Estimation Methods*[2] and embarked on developing the first set of RTF measure-specific savings protocols. To the extent possible, this guide is compatible with the *RTF Guidelines* and with measure-specific savings protocols as developed by the conclusion of the BPA effort.

2.1. Overview of Protocols and Related M&V Documents

In addition to this guide, BPA has developed the following documents, organized by type, to assist the M&V practitioner. (The informal name of the document appears in parentheses.) The documents in the first two categories provide guidance for producing M&V plans compatible with the BPA's custom project requirements as specified in its *Energy Efficiency Implementation Manual.*[3] The latter two categories provide additional resources for the M&V practitioner.

- **Protocols for Producing Comprehensive M&V Plans**
  - *Verification by Energy Use Indexing Protocol (Energy Use Indexing Protocol)*
  - *Verification by Equipment or End-Use Metering Protocol (End-Use Metering Protocol)*
  - *Verification by Energy Modeling Protocol (Energy Modeling Protocol)*
- **Protocols for Producing Engineering Calculations with Verification Plans**
  - *Engineering Calculations with Verification Protocol (ECwV Protocol)*
- **Protocol Application Guides**
  - *Existing Building Commissioning: An M&V Protocol Application Guide (EBCx Application Guide)*
  - *End-Use Metering Absent Baseline Measurement: An M&V Protocol Application Guide (Absent Baseline Application Guide)*

2 Hereinafter, *RTF Guidelines*.

3 Hereinafter, *Implementation Manual.*

➡ Reference Guides

- *Sampling for M&V: Reference Guide (Sampling Reference Guide)*
- *Regression for M&V: Reference Guide (Regression Reference Guide)*
- *Glossary for M&V: Reference Guide (Glossary)*

Table 2-1 provides a brief description of each protocol and savings assurance guidance document and the types of energy efficiency projects addressed by the documents. The table also indicates which documents describe approaches adherent to the *International Performance Measurement and Verification Protocols* (IPMVP).

Table 2-1: Overview of Protocols and Guidance Documents

Document Name	Description and Applicability
	RTF Standardized Savings Approaches and Protocols
RTF Unit Energy Savings (UES)	Measure savings values, included in the *RTF Guidelines*. The UES apply to installation counts of measures for which the RTF has "deemed" per unit energy savings, cost, and load shape based on program evaluation data and engineering estimates.
RTF Calibrated Engineering	Energy savings calculators approved by the RTF (in the *RTF Guidelines*) because they have been calibrated to "individual cases or to the average characteristics and consumption of groups."
RTF Standard Protocols for Site-Specific Savings Estimates	Protocols under development with the potential to be IPMVP-adherent because they are based on pre- and post-installation measurements of energy use. In some cases, where possible and appropriate, the standard protocols may infer pre-installation performance based on post-installation measurements. This is allowed in recognition that it may not always be possible to get sufficient pre-installation data for a valid savings estimate. The protocols are intended to be as rigorous as a fully IPMVP-adherent method.
	BPA Protocols for Producing Engineering Calculations with Verification Plans
Engineering Calculations with Verification	Intended for projects with savings less than 200,000 kWh or projects for which other criteria dictate that a fully IPMVP-adherent protocol is not possible or not reasonable. BPA engineering staff retains discretion as to whether a project with annual energy savings over 200,000 kWh may use this protocol and remain consistent with *Implementation Plan* requirements.
	BPA Protocols for Producing Comprehensive M&V Plans
Verification by Equipment or End-Use Metering	Intended for measures that change load or operating hours, or both load and hours. Savings can be large or small. Can handle non-interactive and interactive measures in some circumstances. *IPMVP Options A and B*
Verification by Energy Indexing	Intended for measures involving equipment whose energy use is impacted by the measure(s) and also by one independent variable (such as production rate) that is not affected by the measure. A simple application of *Verification by Energy Modeling*. Savings can be large or small, but generally not interactive. *IPMVP Options B and C*

Continued

Document Name	Description and Applicability
Verification by Energy Modeling	Intended for measures involving equipment whose energy use is impacted by the measure(s) and also by multiple independent variables that are not affected by the measure. *Modeling* here refers to statistical or other data-driven types of models, rather than engineering models of physical systems. Savings can be large or small. Appropriate for interactions between measures, but the ability to distinguish between savings for each measure is dependent upon the level of sub-metering and the types of measures. *IPMVP Options B and C*
	BPA Protocol Application Guides
Existing Building Commissioning Application Guide	Intended for existing buildings with commissioning projects resulting in multiple measures with interactive effects between measures. This is a specific application of *Verification by Energy Modeling*. *IPMVP Options B and C*
End-Use Metering Absent Baseline Measurement Application Guide	Intended for energy-efficient equipment without a directly-measurable baseline, including newly constructed facilities, major additions to an existing facility, or replacement of failed equipment. This is a specific application of *Verification by Equipment or End-Use Metering*. *IPMVP Option A* – may be *Option B* if available information is a suitable proxy for needed parameters

The BPA protocols, application guides, and reference guides are available at the *BPA M&V Protocol/Guide Regional Stakeholders Group* section of the *Conduit* website at *https://conduitnw.org/Pages/Group.aspx?RID=37* or through BPA.

2.2. Prior Protocols and Related M&V Documents

BPA and the RTF were among the first organizations to set forth guidelines for verifying the savings of site-specific custom projects. The standard of *good* and *best* practice has continued to evolve since they developed the following documents (which the current work replaces for custom measures to be compliant with *Implementation Manual* requirements):

- *Site Specific Verification Guidelines*, BPA (Harding, Gordon & Kennedy), May 1992
- *Energy Savings Verification Protocols*, Regional Technical Forum, September 2000
- The *Conservation Resource Comments Database*, Regional Technical Forum

These documents included the protocols listed in Table 2-2 and are superseded by the documents shown in Table 2-1.

Table 2-2: List of Predecessor Protocols and Guidance Documents

Document Name
RTF Conservation Resource Comments Database*: Deemed Measures Values
RTF Conservation Resource Comments Database: Simplified M&V Measures – Deemed Calculators
BPA Verification by Billing Analysis
BPA Verification by Connected Load Measurement
BPA Verification by Equipment or End-Use Metering
BPA Verification by Energy Indexing
BPA Verification by Hybrid Methods
RTF Group No. 1
RTF Group No. 2
RTF Group No. 3
RTF Group No. 4
RTF Site Specific No. 1
RTF Site Specific No. 2
BPA Commissioning

* A product of the RTF, this is a collection of 59 *Excel* workbooks that creates narrowly defined measures, provides stipulated savings values, and in some cases deemed calculators.

2.3. Considerations in Selecting an M&V Protocol

As a foundation for the specific protocol selection guidance we provide in the next section, here we discuss basis principles pertinent to determining which protocol is appropriate for a given measure. This section summarizes the objectives of M&V, then discusses general selection criteria, and concludes with a discussion of M&V rigor.

2.3.1. M&V Objectives

M&V involves real time and/or retrospective assessments of the performance and implementation of a project. There are two primary principles of M&V:

- To verify that the intended changes to the facility were made, and that those changes have the potential to perform as intended and save energy.
- To measure and document the actual effects of a project (i.e., energy and demand savings) and determine whether it met its ex-ante estimates.

Potential to perform is usually defined as, and based on, whether the right equipment was installed and whether the equipment is operating properly. Actual performance is usually defined as determining the actual savings. For example, if the savings are determined only for the first year of operation, that savings estimate might also be an appropriate estimate of the project's potential to perform in subsequent years.

These two principles of verifying potential to perform and estimating actual project effects should always guide the decision of which protocol or savings assurance approach to use. All of the BPA protocols require verification. Standard M&V also requires measurement of savings, but cost, safety, and other considerations may lead to a less rigorous approach. Practitioners should understand the degree to which the second principle is important for each project – how much uncertainty is permissible in the savings estimate. This selection guide is intended to assist with making decisions regarding the choice of rigor as part of protocol selection.

2.3.2. General Considerations

Perhaps the most difficult issue in conducting measurement and verification (M&V) activities is deciding *how good is good enough*. There is never absolute certainty when determining energy efficiency savings; one is always making an estimate because of the counter-factual circumstances. The *counter-factual* is the energy that would have been used had the measure not been installed.

So, in effect, one is always asking the question: *Actual effects as compared to what*?

For energy efficiency M&V, there are multiple aspects to this question:

- ➡ *To what baseline are you comparing current energy use and is that baseline changing over time?*
- ➡ *Are you able to obtain reliable and sufficient pre- and post-installation measurements of energy use and any independent variables to which that energy use is related?*
- ➡ *How does the certainty (or uncertainty) of savings determination compare with other uncertainties or with the total project savings quantity?* This can be described as deciding how much effort M&V warrants compared with the value of the information obtained.

These general questions come down to practical questions for M&V practitioners about which M&V approach (protocol) to use and what level of certainty (accuracy, reliability, etc.) one should achieve. This guide is intended to help address these questions for BPA efficiency projects. Selection criteria based on these questions (described more specifically below) guide the M&V practitioner in selecting which BPA or RTF M&V protocol to apply.

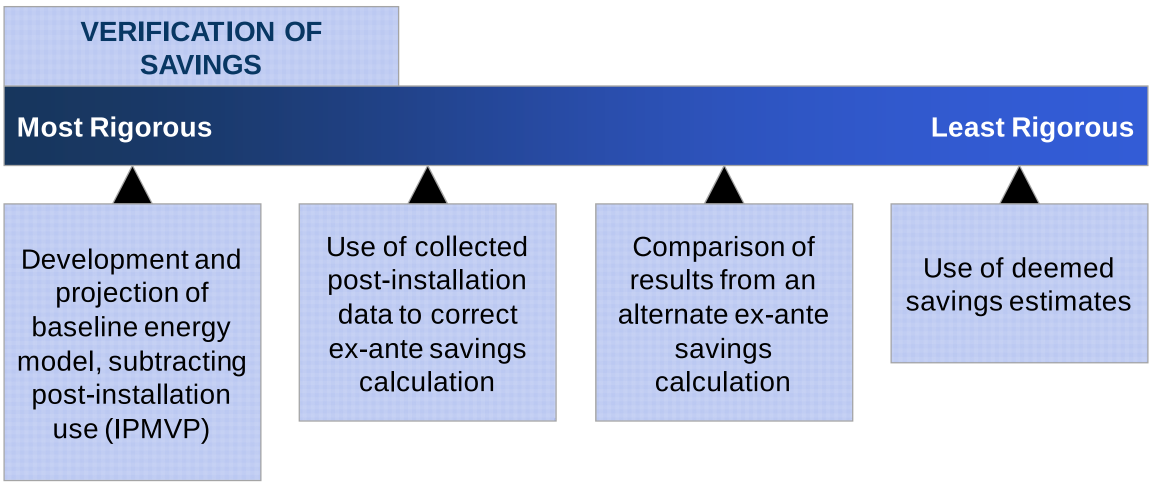
This guide discusses a range of potential selection criteria – more than are included in the flowchart presented in Section 2.4.1 and expounded on in the subsequent sections. The guide discusses additional, potential selection criteria so that all parties involved can be aware of different criteria that might be pertinent to a specific project, and to provide BPA with a list of criteria for consideration in when updating this guide.

2.3.3. M&V Rigor

This document describes various levels of rigor for the savings verification. BPA has historically allowed for a less rigorous level of M&V for certain project types. The less rigorous version was generically called *Light M&V*, referring to types of M&V that did not require pre- and post-installation measurements of energy use. Light M&V typically used engineering calculations of varying degrees of detail. More rigorous M&V was called *standard*, which generally required direct measurement of pre- and post-installation energy consumption and other significant variables.

Figure 2-1 illustrates a range of M&V efforts and relative rigor for site specific, custom projects. In this diagram, the most rigorous methods, which are IPMVP-adherent, are represented on the left while the least rigorous method – that of using deemed savings estimates – is represented on the right.

Figure 2-1: M&V Rigor



As described in Table 2-1, the protocols and guidance documents available for the region range from the most rigorous, IPMVP-adherent approaches, to the least rigorous use of deemed savings. The *Engineering Calculations with Verification Protocol*, which replaces the former Light M&V approach, spans the middle two boxes. The RTF standardized methods – rows two and three of Table 2-1 – generally fit in the left two boxes. The RTF standardized methods, while including deemed values, base savings estimates on prior, rigorous M&V or evaluation, detailed and calibrated calculations, or regionally-approved protocols.

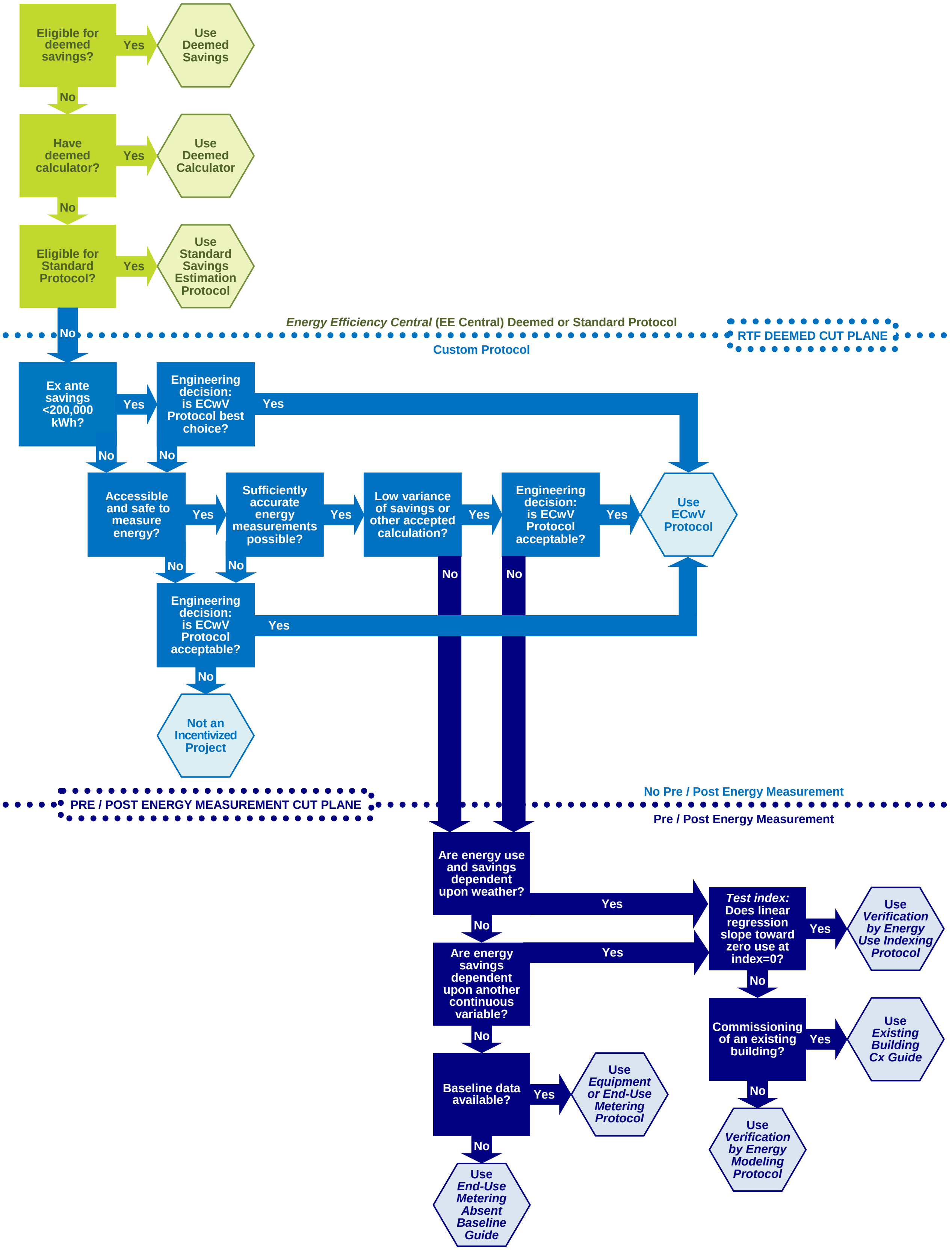
2.4. Protocol Selection

2.4.1. Protocol Selection Graphic

Figure 2-2 provides a flowchart for protocol selection.

First, note the three regions of the flowchart. The upper portion, above the first cut plane (dotted line) and shown in shades of green, describes measures addressed by the RTF standardized protocols. The middle portion, shown in shades of blue, represents custom measures for which the M&V plan does not require the use of pre-and post-installation energy measurements and instead requires the less rigorous *Engineering Calculations with Verification*. The lower portion of the graphic, below the second cut plane and shown mostly in dark blue, represents custom measures requiring the comprehensive IPMVP-adherent protocols described in Table 2-1.

Figure 2-2: Protocol Selection Flowchart



2.4.2. First Criteria Set (Upper Cut Plane)

The first level of determining the appropriate savings assurance approach (the region above the first cut plane in Figure 2-2) simply considers the project or measure's technology and the type of facility within which it is implemented. The first level of selection addresses the following question:

➡ ***Does a regional (RTF) standard approach exist for estimating the project or measure savings?***

This question provides the dividing line between RTF standardized methods and the BPA protocols. The standard approach could be one of the following:

➡ RTF, BPA deemed savings value (unit energy savings; row 1 in Table 2-1)

➡ RTF, BPA calibrated engineering approach (UES calculators; row 2 in Table 2-1)

➡ RTF-approved standard protocols for site-specific savings estimates (row 3 in Table 2-1)

In the *RTF Guidelines*, the first two are included in the description for *Unit Energy Savings* (UES), with standardized M&V calculations being described in the section on *Calibrated Engineering*. The third approach is included in the *RTF Guidelines* as *Standard Protocols for Site-Specific Savings Estimates*, or abbreviated as *standard protocol*.

Since the list of deemed values, calculators, and standard protocols may grow or change over time, this selection guide does not provide specific selection steps with regard to them, just the question as to whether an applicable, specific RTF approach exists.

2.4.3. Second Criteria Set (Middle Cut Plane)

Should an applicable, specific RTF approach not exist, then the decision regarding savings assurance approach drops below the first cut plane in Figure 2-2, into the first of two realms of protocols developed by BPA. The M&V practitioner uses a second set of criteria to assess these projects. These criteria are associated with determining the level of effort and rigor required for a particular project, and whether project limitations dictate a particular approach. This is where a determination is made to develop a comprehensive M&V plan, based on pre- and post-installation measurements of energy use (which drops the practitioner into the third criteria set), or to develop an M&V plan based on engineering calculations with verification (abbreviated in Figure 2-2 as *ECwV*).

The M&V practitioner has the option of preparing for projects with savings under 200,000 kWh annually with an *Engineering Calculations with Verification M&V Plan*. *ECwV* can also be used for projects that meet other requirements, as discussed subsequently and illustrated in Figure 2-2. BPA also gives M&V practitioners discretion to propose an ECwV approach in response to unforeseen circumstances, such as project and incentive timing issues that result in an inability to get sufficient energy measurements for another approach.

Verification is required with all non-deemed approaches, including engineering calculations. Verification corroborates the measure installation and operation, as well as the engineering calculations underpinning the pre-installation savings estimate, but does not include post-installation energy monitoring over time or the independent development of a post-installation savings estimate.

For projects larger than the 200,000 kWh threshold, an appropriate M&V protocol based on pre- and post-installation energy measurements should be the default choice. The use of *ECwV* for projects over 200,000 kWh is discouraged unless there are clear reasons why a comprehensive M&V protocol should not be used. However, there are reasons, such as safety, that may preclude the use of pre- and post-installation energy measurements. Hence, some projects with anticipated savings over 200,000 kWh annually may use *ECwV* rather than comprehensive M&V.

As shown in Figure 2-2, if the ex ante savings estimate is less than 200,000 kWh annually, then the M&V practitioner can decide, subject to BPA's engineering approval, whether the *Engineering Calculations with Verification Protocol* (*ECwV* in the figure) is acceptable for the project. If the savings are greater than 200,000 kWh, or the analysts initially think engineering calculations are not acceptable, then one proceeds to answer additional questions.

- ***Are the needed measurement locations accessible and safe?***
  - *If no:* the analyst has another chance to decide whether *ECwV* is acceptable.
  - *If yes:*
- ***Can sufficiently accurate measurements be made?***
  - *If no:* again, is *ECwV* acceptable?
  - *If yes:*
- ***Is there an acceptable existing calculation (not part of the RTF standardized savings), or is it expected that a reliable calculation could be developed such that variance of actual savings relative to the calculation is expected to be low?***
  - *If no:* then the analyst should select one of the protocols using pre- and post-installation energy measurements, following the process described in the next section.
  - *If yes:* then the analyst gets one more chance to decide whether *ECwV* is acceptable for the project.

If it is not possible or safe to make the required energy measurements, or the measurements cannot be made with sufficient accuracy, and yet *ECwV* is not acceptable for the project, then no M&V can be performed and the project is not eligible for incentives.

The following are a broader list of six, mostly subjective, guidance criteria suggested for selecting whether *ECwV* or a comprehensive M&V protocol that is IPMVP-adherent should be used. This list covers issues beyond just the size of the project to address uncertainty and the value of information obtained, and can be used by M&V staff for further guidance when deciding whether *ECwV* is warranted, acceptable, and, indeed, the best choice for the project.

- **Regularity of Operating Periods:** Where operating patterns are driven by routine events and the operating periods can be estimated with ease and accuracy, then *ECwV* may be of sufficient accuracy. However, if operating periods vary with irregular requirements, such as weather or plant production effects, care must be taken to measure the operating periods and thus comprehensive M&V is more likely to be appropriate.

- **Savings Persistence:** Where the continuing success of the retrofit is in doubt (e.g., control changes subject to human interaction), it is dangerous to base estimates on one-time observations of performance; thus comprehensive M&V is more likely to be appropriate and the reporting period should be extended.

- **Size of Savings Relative to Utility Meter Total Use:** Where expected savings are very small (less than 5% to 10%) as compared to total usage recorded on a meter, sub-meters may need to be added so that savings can be identified with reasonable precision. This can make the cost of an IPMVP-adherent approach too great, and thus *ECwV* may be more appropriate. (Fortunately, the cost of metering is declining and sub-metering is increasingly used to assist with daily facility operations, making sub-metering data more available for M&V.)

- **Complexity of Measure Interactions with Other Measures:** *ECwV* is appropriate with single measures or multiple measures at a facility where they do not interact in terms of their energy use. If there are multiple measures in the facility with complex interactions that cannot be accounted for through simple estimates of individual measure performance, then comprehensive M&V should be used, with more detailed measurements and analyses.

- **Opportunity for Lessons Learned:** If there are characteristics about this measure or participant sponsor (e.g., there are or may be many similar measures or applications) that make it important to have a reliable estimate of savings for use in other projects, then comprehensive M&V is likely more appropriate.

There are other criteria that could be used, but they are either less important than the criteria in Figure 2-2 or are broadly covered by the above criteria. These criteria and their implications include:

- **Consideration of energy (kWh) versus demand savings (kW)** – demand savings may be harder, or easier, to estimate with engineering calculations than with comprehensive M&V

- **Certainty of ex-ante technical results (and user or participant impact on results)** – the less certainty, the greater the need for comprehensive M&V

- **Expected measure persistence after installation** – the less likely persistence, the greater the need for comprehensive M&V

- **Type of measure; increasing levels of complexity** – the greater the complexity, the greater the need for comprehensive M&V

- **Equipment change only** – *ECwV* may suffice

- **Operational change only** – *ECwV* may suffice

- **Equipment and operational change** – comprehensive M&V likely needed

- **Number of measures affecting the same electric utility meter –** are there interactive effects and are estimates of individual measure savings needed; interactive effects necessitate comprehensive M&V; the ability to estimate individual measure savings differs among the protocols

➡ **Signal to noise issues –** how large the savings are compared to baseline or project energy use; whether process loads being retrofitted can be isolated by meter; whether metered data correlates well with available independent variable data; appropriate protocol varies with the specific circumstances

2.4.4. Third Criteria Set (Bottom Cut Plane)

If pre- and post-installation measurements can be safely and successfully made, then the M&V practitioner can use one of the BPA comprehensive protocols. For projects with savings over 200,000 kWh where there is no applicable RTF standardized approach, a BPA comprehensive protocol should be the default choice, with *ECwV* chosen only if there are compelling reasons persuasive to a BPA energy efficiency engineer.

The first decision box below the *Pre/Post Energy Measurement Cut Plane* in Figure 2-2 asks:

➡ ***Are energy use and savings dependent upon weather?***

- *If yes:* a data-driven model approach should be selected.
- *If no:*

➡ ***Are energy savings dependent upon another continuous variable?***

- *If yes:* a data-driven model approach should be selected.
- *If no:* see the next arrow below.

There are three BPA protocols associated with data-driven models: *Energy Modeling*, *Energy Use Indexing*, and the *EBCx* (*Existing Building Commissioning) Application Guide*. Recall that data-driven refers to statistical models, rather than engineering models of physical systems.

If the regression relationship of energy use with the independent variable leads to zero energy use when the value of the independent variable is zero, then the M&V practitioner should use *Energy Use Indexing*.[4]

Note that *Energy Indexing* can be used even for relationships with weather by establishing an index using a temperature difference. For example, energy use of cooling equipment (not including ventilation fans) may reach zero at 55º F. An index of Temp-55 (defined as temperature minus 55) could be established and the *Energy Indexing Protocol* used. In most cases, it is probably clearer to use the full *Energy Modeling Protocol*, but an indexing approach may be simpler and appropriate for some applications.

If the regression relationship does not slope toward zero, then the next question asks:

➡ ***Is the project the commissioning of an existing building?***

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[4] See *Regression for M&V: Reference Guide*, one of the BPA protocol documents and guides.

- *If yes:* the *EBCx Application Guide* should be used.
- *If no:* use the *Energy Modeling Protocol*, of which the *EBCx Guide* is a specific application.

If answers to the questions regarding dependencies on independent variables are both no: then either *End-Use Metering Protocol* or the *Absent Baseline Application Guide* should be selected. The M&V practitioner should use the *End-Use Metering Protocol* if a measured baseline is available and, obviously, use the *Absent Baseline Application Guide* if the baseline cannot be measured. The *Absent Baseline Application Guide* should thus be used for efficient equipment or systems installed in newly constructed or renovated space.

3. Example M&V Plan

This chapter provides an M&V plan as an illustrative example. The M&V plan is shown in a memorandum format, with sections that describe the key technical approach to verifying savings.

The plan's brief format is intended to facilitate documentation of the key M&V activities and, as such, it is not intended to be an IPMVP-adherent plan (although when using a comprehensive protocol, the M&V procedures themselves are adherent). Of the thirteen topics described by IPMVP and thus constituting an IPMVP-adherent M&V plan, we include nine of them – or slight variations on them – in this example. These nine topics are:

1. Baseline Conditions
2. ECM Intent
3. Measurement Boundary
4. Selected BPA Protocol
5. Baseline Energy Use Measurements
6. Post-Installation Measurements
7. Description of Analysis Procedures (including the basis for adjustments)
8. Responsibilities of Involved Parties
9. Savings Report Contents and Frequency

Planning an M&V project is best done after becoming familiar with the facility where the energy conservation measures (ECMs) will be installed. Required resources, such as energy or equipment monitoring systems (building automation systems or industrial SCADA systems, etc.), may be present and available for use to complete the savings verification analysis. The feasibility of making certain required measurements will be better known following site visits.

Because ECMs are often installed over an extended period of time, M&V plans provide a reminder of what M&V protocol to implement, what activities must be carried out following installations, and how baselines were developed. Personnel assigned to the M&V project may change as well, and the M&V plan facilitates orientation of new project personnel.

This example M&V plan is based on Example #2 in the BPA *End-Use Metering Protocol*.

3.1. Example M&V Plan: Automobile Factory Paint Shop Exhaust Fans

Assigned Personnel: ____________________ Date: ______________________________

Facility Name: ____

ECM Description: ______________________ BPA Protocol: End-Use Metering

3.1.1. Baseline Conditions

Exhaust fans in the paint shop at an automobile factory operated continuously throughout two 8-hour work shifts (6:00 am to midnight) during each work week. There were a total of 4 days of maintenance downtime in the previous year. There were four paint booths within the shop, each with 60-hp constant speed fans.

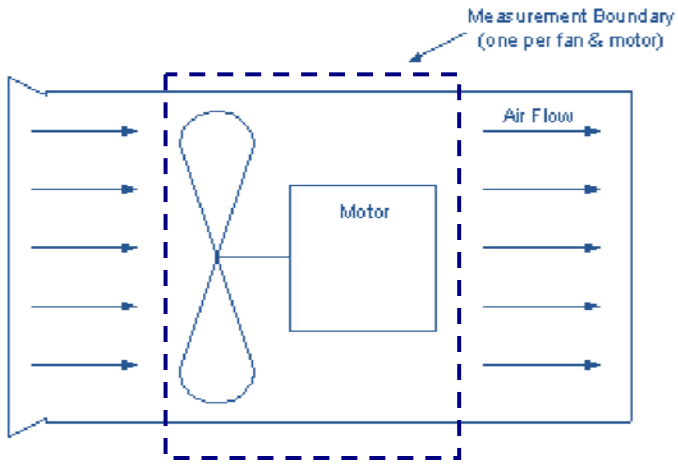
3.1.2. ECM Intent

Controls will be installed in each paint shop to monitor air quality and shut off the exhaust fans when the paint shop is not in use, or when air quality is at acceptable levels. This is expected to reduce the number of fan operation hours significantly. Preliminary estimates indicate over 1,000 hours in reduced run time.

3.1.3. Measurement Boundary

The measurement boundary is drawn around each exhaust fan, as shown in Figure 3-1. The exhaust fan motors will not be affected by the planned changes. The only effect of the ECM was to reduce the hours of operation.

Figure 3-1: System Sketch



3.1.4. BPA Protocol Selection

BPA's *End-Use Metering Protocol* will be employed for this project. The *Option A: Key Parameter Measurement M&V Option* will be used. The key parameter is the number of annual operation hours of the exhaust fans. The exhaust fan power will be estimated based on motor nameplate data and a spot measurement on each fan.

3.1.5. Baseline Energy Use Measurements

The baseline equipment operates as a constant load timed schedule system (CLTS). The nameplate horsepower rating from each fan motor will be collected; the brake horsepower will be calculated and compared against a spot measurement of each fan's power use when operating, to verify the engineering assumption of each fan's power draw.

The fan operation schedule will be verified using a motor status logger on each of the four fans. Status logging was conducted over a 2-week period to verify that the fans operated continuously over both work shifts each working day.

3.1.6. Post-Installation Measurements

After the controls are installed, the equipment is still expected to operate as a constant load. However, the operation schedule will change to a variable schedule system (CLVS) as the exhaust fans cycle on and off as the cars move through the paint shop.

Each fan motor's power use when operating will be verified that it is unchanged, using a spot measurement of fan motor power. The exhaust fan schedule will be monitored by installing motor status loggers on each fan motor for one month duration. In addition, the paint shop logs of cars entering and leaving the shop during the monitoring period will be obtained.

3.1.7. Description of Analysis Procedures

Per the *End-Use Metering Protocol*, the characteristic load and schedule category in the baseline and post-installation periods must be named.

- ➡ The baseline category is CLTS.
- ➡ The controls upgrade only affects hours of operation – enabling and operating the exhaust fans only as cars are moved through the paint shop. The post-installation category is CLVS.

The 60-hp fan motors will be measured with one-time spot measurements in the baseline period, while the fan operation hours will be measured over a two-week period using motor status loggers on each exhaust fan.

In the post-installation period, the fans operation hours per car will be determined, based on logging of operation hours over a month in the post-installation period and the number of cars moved through the paint shop in the same time period. The number of cars will be determined from the paint shop logbooks.

Annual energy use will be calculated from Equation 2, from Table 3-2 of the *End-Use Metering Protocol*:

- **Equation 2:** $kWh_{saved} = kW_{base} \cdot HRS_{base} - kW_{base} \sum_i HRS_{post,i}$

Potential non-routine adjustments may include: paint shop down time and changes in vehicle paint requirements. In each event, the number of operation hours will be affected. The impact of these events on the operation hours will be determined by reinstalling status loggers to determine the impacts.

3.1.8. Responsibilities

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3.1.9. Savings Report Content and Frequency

One savings report is planned for this project. It will be completed approximately two months after the fan controls have been installed and commissioned to accommodate the one month of motor status logging planned for the post-implementation period.

All data collected will be formatted and provided in a spreadsheet. This includes:

- Baseline period motor status trend logs
- Baseline period spot measurements of motor power
- Post-installation period motor status trend logs
- Post-installation period spot measurements of motor power
- Paint shop logs of number of cars painted over the past year

In addition, the spreadsheet report will provide all calculations and assumptions. Equations used in the spreadsheet will be clearly labeled, and the analysis made straightforward to follow and review.

A short report of the results of the M&V analysis will be provided. This report will summarize the facility equipment that was modified, describe the ECM and its effect on operation hours, provide reference to the M&V Plan, and note any changes. The relevant BPA M&V protocol will be cited and calculations summarized, and savings results clearly labeled.

4. 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.

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BPA. 2011. *Energy Efficiency Implementation Manual*. Portland, Ore.: Bonneville Power Administration.

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

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Regional Technical Forum. *Conservation Resource Comments Database*. Portland, Ore.: Northwest Power & Conservation Council.

Note, this application was used to develop the 5th Power Plan and is no longer available. For further information see: *http://www.nwcouncil.org/comments/default.asp*.

Regional Technical Forum. 2011. *Guidelines for the Development and Maintenance of RTF Savings Estimation Method*. Portland, Ore.: Northwest Power & Conservation Council.

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