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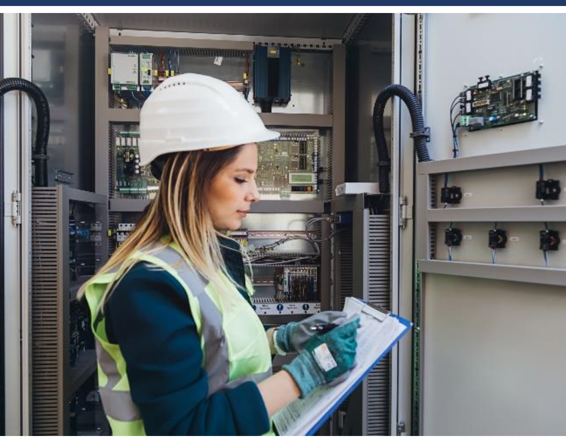
Measurement & Verification (M&V) Protocol Selection Guide and Example M&V Plan

March 2018




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

Version 2.0

March 2018

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Bonneville Power Administration

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Table of Contents

1. Introduction

1.1. Purpose

This *Measurement & Verification (M&V) Protocol Selection Guide and Example M&V Plan* (*Protocol Selection Guide)* aids in selecting the appropriate Bonneville Power Administration (BPA) M&V protocol and designing an M&V plan. Originally developed in 2012, this *Protocol Selection Guide* is one of ten documents produced by BPA to direct M&V activities. This updated version provides an overview of BPA's M&V protocols and application and reference guides, and gives direction based on practical considerations and recent regional M&V experience as to the appropriate guide to use for a given energy efficiency project. It also provides an example M&V plan.

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

1.2. Protocols Version 2.0

BPA revised the protocols described in this guide in 2018. BPA published the original documents in 2012 as Version 1.0. The current guides are Version 2.0.

The protocol authors are preparing under this contract a subsequent version, Version 2.1, that will add examples to the V2.0 documents.

1.3. How is M&V Defined?

BPA's *Implementation Manual* (the IM) defines measurement and verification as "the process for quantifying savings delivered by an energy conservation measure (ECM) to demonstrate how much energy use was avoided. It enables the savings to be isolated and fairly evaluated."[1] The IM describes how M&V fits into the various activities it undertakes to "ensure the reliability of its energy savings achievements." The IM also states:

> *The Power Act specifically calls on BPA to pursue cost-effective energy efficiency that is "reliable and available at the time it is needed."[2] […] Reliability varies by savings type:*

[1] 2017-2019 Implementation Manual, BPA, October 1, 2017. *https://www.bpa.gov/EE/Policy/IManual/Documents/IM_2017_10-11-17.pdf*

[2] Power Act language summarized by BPA.

UES, custom projects and calculators.[3,4] *Custom projects require site-specific Measurement and Verification (M&V) to support reliable estimates of savings. BPA M&V Protocols direct M&V activities and are the reference documents for reliable M&V. For UES measures and Savings Calculators, measure specification and savings estimates must be RTF approved or BPA-Qualified.*[5]

This Protocol Selection Guide includes a flow chart providing a decision tree for selecting the M&V protocol appropriate to a given custom project and addressing prescriptive projects using UES estimates and Savings Calculators.

M&V is site-specific and required for stand-alone custom projects. BPA's customers submit bundled custom projects (projects of similar measures conducted at multiple facilities) as either an M&V Custom Program or as an Evaluation Custom Program; the latter requires evaluation rather than the site-specific M&V that these protocols address.

1.4. Background

BPA contracted with a team led by kW Engineering, Inc. to assist the organization in revising the M&V protocols that were published in 2012 and used to assure reliable energy savings for the custom projects it accepts from its utility customers. The team conducted a detailed review and user assessment of the 2012 M&V Protocols and developed the revised version 2.0 under Contract Number 00077045.

The kW Engineering team is comprised of:

- kW Engineering, Inc. (kW), led by David Jump, Ph.D., PE, CMVP
- Research into Action (RIA), led by Marjorie McRae
- Demand Side Analytics (DSA), led by Jesse Smith

BPA's Todd Amundson, PE and CMVP, was project manager for the M&V protocol update work. The kW Engineering team compiled feedback from BPA and regional stakeholders, and the team's own review to revise and update this 2018 Protocol Selection Guide.

1.5. Glossary

Volume 10, *Glossary for M&V: Reference Guide*, provides a complete glossary for the suite of M&V protocol documents.

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3 UES stands for Unit Energy Savings and is discussed subsequently. In brief, it is a stipulated savings value that region's program administrators have agreed to use for measures whose savings do not vary by site (for sites within a defined population). More specifically UES are specified by either the Regional Technical Forum – RTF (referred to as "RTF approved") or unilaterally by BPA (referred to as BPA-Qualified). Similarly, Savings Calculators are RTF approved or BPA-Qualified.

4 Calculators are discussed subsequently. Calculators estimate savings that are a simple function of a single parameter, such as operating hours or run time.

5 https://www.bpa.gov/EE/Policy/IManual/Documents/IM_2017_10-11-17.pdf, page 1.

2. Protocol Selection Guidance

This *Protocol Selection Guide* is designed to assist the M&V practitioner charged with estimating site-specific energy savings for custom projects to select the appropriate BPA M&V protocol. However, unique project characteristics or concerns identified by BPA, utility staff, or those conducting the M&V activities, may result in selection of a different protocol than suggested by the criteria given in this guide.

2.1. Overview of Protocols and Related M&V Documents

BPA has developed this and nine other documents in support of custom project M&V (Table 2-1). The table provides a brief description of each document, organized by type of document. It also indicates which documents describe approaches adherent to the *International Performance Measurement and Verification Protocols* (IPMVP). The document name in parenthesis is its short-form name.

Table 2-1: Overview of Protocols and Guidance Documents

Document Name	Description and Applicability	IPMVP Adherent
	BPA Fully IPMVP-Adherent Protocols (Comprehensive M&V)	
Verification by Equipment or End-Use Metering Protocol (End-Use Metering)	Intended for measures that change load or operating hours, or both load and hours. Appropriate for non-interactive measures. Can address interactive measures in limited circumstances.	Adherent with IPMVP *Options A and B*
Verification by Energy Modeling (Energy Modeling)	Intended for measures involving equipment whose energy use is impacted by the measure(s) and by multiple independent variables not affected by the measure. 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. *Modeling* here refers to statistical or other data-driven types of models, not engineering models of physical systems. Involves development and projection of a baseline energy model, subtracting post-installation use, per avoided energy consumption methods. May also apply normalized savings methods, where baseline and post-project energy models are developed and adjusted to a common set of conditions.	Adherent with IPMVP *Options B and C*
Verification by Energy Use Indexing Protocol (Indexing)	Intended for measures involving equipment whose energy use is impacted by the measure(s) and by a single independent variable (such as production rate) that is not affected by the measure. Appropriate for non-interactive measures. Can address interactive measures in limited circumstances. This protocol is an application of *Verification by Energy Modeling* for the simple case of one-variable models.	Adherent with IPMVP *Options B and C*

Document Name	Description and Applicability	IPMVP Adherent
	BPA Protocols for Conducting Engineering Calculations with Verification	
Engineering Calculations with Verification (ECwV)	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 appropriate. 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 the IM requirements. Uses collected post-installation data to correct ex-ante savings calculations.	Not adherent
	BPA Protocol Application Guides	
End-Use Metering Absent Baseline Measurement Application Guide (Absent Baseline)	Intended for energy-efficient equipment without a directly-measurable baseline, including: • newly constructed facilities • major additions to an existing facility, and • replacement of failed equipment. This is a specific application of *Verification by Equipment or End-Use Metering*.	Adherent with IPMVP *Option A* Can be adherent with *Option B* if the available information provides suitable proxies for needed parameters
Existing Building Commissioning Application Guide (EBCx)	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*.	Adherent with IPMVP *Options B and C*
	BPA M&V Reference Guides	
M&V Protocol Selection Guide and Example M&V Plan (Selection Guide)	This document. Guides the M&V practitioner in determining which protocol is appropriate for the project. Illustrates the elements needed in an M&V plan by providing an example plan.	Not protocols
Sampling for M&V	Provides a simple explanation of sampling terms, principles, and methods. Useful for projects comprised of many identical measures, such as lighting.	
Regression for M&V	Provides a simple explanation of regression modeling terms, principles, and methods. Companion to the *Energy Modeling* guide.	
Glossary for M&V	Provides definitions of technical terms used in the guides.	

The suite of BPA protocols, application guides, and reference guides are available at *https://www.bpa.gov/ee/policy/imanual/pages/im-document-library.aspx*.[6]

6 In addition to these protocols, BPA has published an Energy Smart Industrial (ESI) Monitoring, Targeting, and Reporting (MT&R) Reference Guide. BPA considers Strategic Energy Management project savings that have been verified by following that guidance to have been measured and verified. BPA's ESI Energy Performance Tracking team conducts these analyses for all ESI projects.

2.2. Qualifications of the M&V Practitioner

The M&V practitioner should have prior experience in conducting M&V, or a background in building science engineering or building modeling. The practitioner should understand the IPMVP Options A, B, C, and D and the BPA M&V protocols.

The practitioner might consider obtaining, but is not required to hold, CMVP certification (Certified M&V Professional).

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 basic principles guiding the selection of a protocol appropriate for a given custom project.

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 defined as, and based on, whether the right equipment was installed and whether the equipment is operating properly. Actual performance is 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 the BPA protocols require verification. IPMVP-adherent M&V also requires measurement of savings, but M&V costs, M&V duration, safety requirements, and other considerations may lead to an alternate or 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. Determining How Good Is Good Enough?

Perhaps the most challenging 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?* Different project circumstances require different baseline definitions. The choice is between an existing conditions baseline or a current practice baseline, discussed further below.
- ➡ *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?* This question concerns issues such as whether the practitioner might be able to remotely collect the required data, or how accessible measurement locations are and how safely measurements can be made when the practitioner needs to visit the site to conduct direct measurements or install loggers. Safety policies of the governing organization must be followed. On-site data collection activities can be expensive and may require multiple visits to set and retrieve instruments. These factors should also be considered, as they can increase the M&V project’s costs and time until delivery of the final M&V report, to a point that makes the approach impractical for the project.
- ➡ *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.

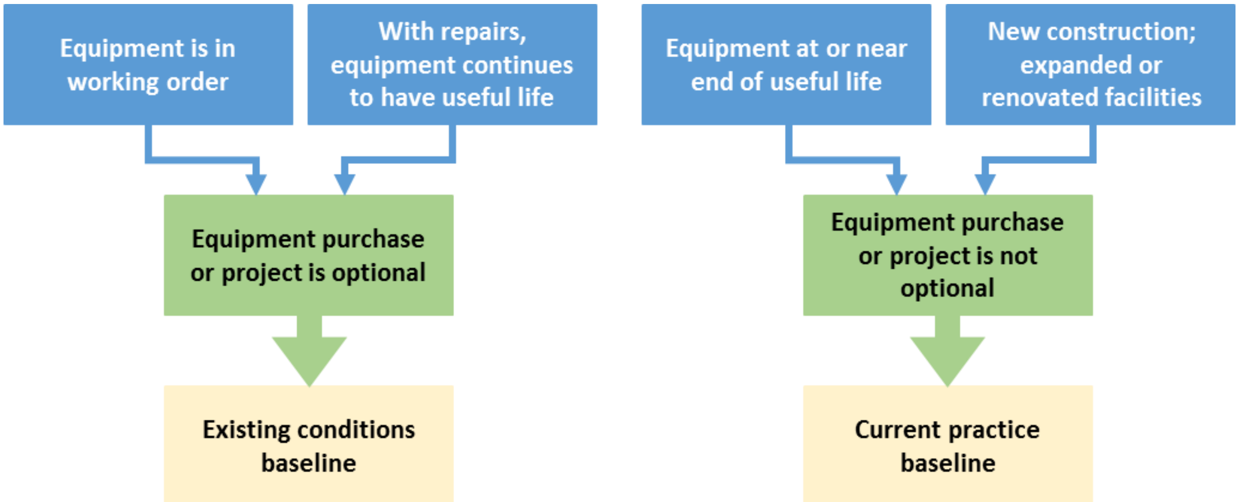
These broad questions generate practical considerations about which M&V approach (protocol) is appropriate to use and what level of certainty (accuracy, reliability, etc.) one should achieve. This guide aims to help address these questions for BPA energy efficiency custom projects. Selection criteria based on these and other questions (described more specifically below) guide the M&V practitioner in selecting which BPA M&V protocol to apply.

The choice of baselines typically depends on whether or not the project or equipment purchase is optional. The purchase or project is optional when the equipment replacement or system redesign occurs before the end of the equipment’s or system’s useful life. Building owners commonly undertake optional projects when the expected energy and non-energy benefits (such as increased productivity) warrant the expense. The equipment to be replaced may be in working order or may need repairs, if with repairs the building owner can reasonably assume the equipment would have more than a year of useful life remaining. Such optional projects typically warrant existing baseline conditions, as those are the conditions that would prevail were the owner to take no action.

The equipment or project is not optional when the equipment is at or near (within one year of) the end of its useful life, or when the equipment or project is necessitated by new construction, including expanded or renovated facilities. The M&V practitioner typically should use the current practice efficiency level for the baseline. When the practitioner uses a current practice baseline, the efficiency level of the baseline equipment must be consistent with any state or local mandates for new equipment, which may vary from city to city and state to state.[7]

Figure 2-1 illustrates this guidance for selecting the appropriate baseline.

Figure 2-1: Guidance for Selecting Appropriate Baseline



Source: Research Into Action

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.

[7] The following websites hosted by Washington State University's Energy Program, the Northwest Energy Efficiency Council, and the Northwest Energy Efficiency Alliance provide information on mandates for new equipment among jurisdictions in the region:
(1) *http://www.energy.wsu.edu/BuildingEfficiency/EnergyCode.aspx*,
(2) *https://www.neec.net/energy-codes/*, and
(3) http://neea.org/initiatives/codes-standards/codes.

2.4. Protocol Selection

2.4.1. Protocol Selection Flow Chart

Figure 2-2 provides a flowchart for protocol selection.

The **upper portion**, shown in shades of green, describes prescriptive projects that do not require M&V.

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 Protocol*. The flow chart shows an option in the middle portion when conditions merit use of the *Verification by Energy Modeling Protocol*, as this method is often cost effective to implement when data are available. The *Verification by Energy Modeling Protocol* option may be implemented independently or in association with the *ECwV Protocol*, if the listed criteria are met.

The **lower portion**, shown in dark blue, represents custom measures requiring the comprehensive IPMVP-adherent protocols described in Table 2-1. Projects requiring these IPMVP-adherent methods should have larger expected savings, generally above 200,000 kWh annually, so that the amount of savings justifies the effort and cost.

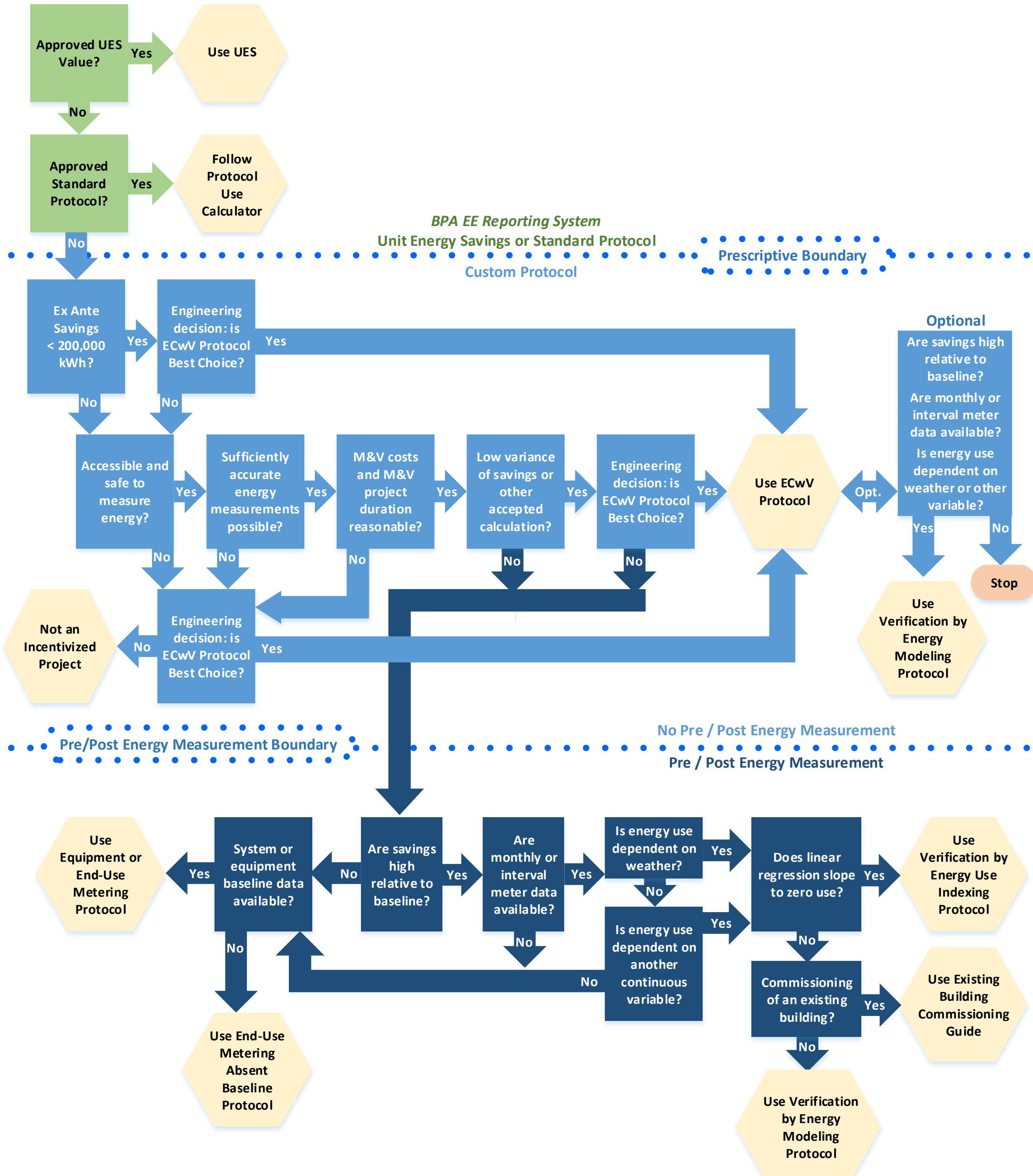
The M&V practitioner should note the following before referring to the flowchart:

1. Practitioners will be conducting M&V on the custom project level, not necessarily on individual measures within the project (although this is warranted in some cases). The decision criteria described in the flow chart thus relate to the whole project.

2. Practitioner should comply with their organizations' safety policies, as well as include safety as a discretionary factor in protocol selection. In some cases, an organization's safety policy may preclude the practitioner's use the protocol indicated by the protocol selection criteria as illustrated in the flow chart.

3. M&V is site-specific and required for stand-alone custom projects. The flowchart does not address projects bundled into an Evaluation Custom Program.

Figure 2-2: Protocol Selection Flowchart



2.4.2. Prescriptive Projects: Upper Portion of the Flow Chart

Prescriptive projects comprise two types of measures:

- Measures whose savings do not vary by site[8]
- Measures whose savings vary by site in an approved relationship with a simple operating characteristic, such as operating hours or run time

The practitioner produces verified project savings for measures whose savings do not vary by site by verifying the number of units installed and applying Unit Energy Savings (UES) values. The RTF has approved UES for dozens of measures; in addition, BPA designates some measures as BPA-Qualified or provisionally deemed.[9,10]

Verified project savings for measures whose savings vary by site are produced by using the BPA-Qualified savings calculator or following the RTF Standard Protocol and using the associated savings calculator. The calculator estimates project savings based on verified simple operating characteristics, such as run time, that drive the savings calculations. BPA Interim Solution 2.0 webpage provides links to Savings Calculators (organized by sector), [11] which can also be accessed through BPA's Implementation Manual Document Library.[12]

2.4.3. Engineering Calculations with Verification: Middle Portion of Flow Chart

Custom projects require M&V as described in the middle and lower portions of the flow chart. The M&V practitioner uses a second set of criteria to assess these projects. These criteria address the level of effort and rigor required for a project, and how project limitations (safety, cost, duration, etc.) influence the approach. At this juncture, the practitioner determines whether 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*).

In this second criteria set there is an option to implement one pre- and post-installation energy use measurement method using the *Verification by Energy Modeling Protocol*. Implementing this method is contingent on the availability of data from utility meters, dependence of building use on weather and/or another continuous variable(s), and whether the savings will be a

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8 For sites of a specific population type, typically defined by such descriptors as sector, building type, and climate.

9 BPA's webpage "Energy Efficiency Interim Solution 2.0 Files" provides a link to the RTF approved UES Measures List. (*https://www.bpa.gov/EE/Policy/Solutions/Pages/default.aspx*)

10 Version 6.0 of the list, effective October 1, 2017, provides an Excel worksheet of 2,299 active UES. Note that a UES is a combination of measure type (nearly 60 types, such as ductless heat pump), measure specifics (such as single head ductless or ducted mini-split), and application specifics (such as single family existing housing in a certain heating and cooling zone, of size greater than 4000 SF).

11 BPA's webpage "Energy Efficiency Interim Solution 2.0 Files" provides a link to the approved calculators. *https://www.bpa.gov/EE/Policy/Solutions/Pages/default.aspx*

12 *https://www.bpa.gov/ee/policy/imanual/pages/im-document-library.aspx*

significant fraction of annual baseline energy use. With available tools such as ECAM, and utility and weather data, the energy modeling method is straightforward to implement, and may provide sufficient rigor. This approach may be used as an alternate to the *ECwV* approach, or may be implemented in addition to an *ECwV* approach.

The M&V practitioner has the option of applying an *Engineering Calculations with Verification* M&V Plan for projects with annual savings below 200,000 kWh. The practitioner can also use *ECwV* for projects that meet other requirements, as discussed subsequently and illustrated in Figure 2-2. BPA also allows M&V practitioners to request approval from the BPA engineer to use the *ECwV* approach on projects saving 200,000 kWh or more in response to unforeseen circumstances, such as project and incentive timing issues that prevent obtaining sufficient energy measurements for other verification approaches.

Verification is required with all non-prescriptive 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 annual savings threshold, the practitioner should select an appropriate M&V protocol based on pre- and post-installation energy measurements. The use of *ECwV* for projects over 200,000 kWh is discouraged unless there are obvious reasons why a comprehensive M&V protocol is inappropriate. Reasons such as safety, M&V costs, and project duration 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. The basis for selecting the *ECwV* protocol for projects with expected savings over 200,000 kWh should be documented in the M&V plan or savings report for the project.

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*) 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:* go to next step.

➡ ***Can sufficiently accurate measurements be made?***

- *If no:* again, is *ECwV* acceptable?
- *If yes:* go to next step.

➡ ***Are M&V costs and/or M&V project duration (duration includes time required in baseline and post-installation periods for site visits, data collection, analysis, and reporting) within reason for the project stakeholders?***

- *If no:* again, is ECwV acceptable?
- *If yes:* go to next step.

➡ ***Is there an acceptable existing calculation (not part of the RTF Standard Protocol or BPA-Qualified)?***

- *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 practitioner should extend the reporting period.

➡ **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, less important criteria that M&V practitioners might use; 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 savings estimate (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. IPMVP-Adherent M&V: Lower Portion of Flow Chart

If pre- and post-installation measurements can be safely and successfully made, and M&V costs and duration are not barriers, then the M&V practitioner can use one of the BPA comprehensive protocols. For projects with estimated annual site savings over 200,000 kWh where there is no applicable prescriptive project approaches, 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 Boundary* in Figure 2-2 asks:

- ➡ ***Are savings high relative to baseline period energy use?***

- *If yes:* a data-driven model should be selected.
- *If no:* a system or equipment level M&V protocol should be used.

➡ ***Are monthly or interval meter data available?***

- *If yes:* a data-driven model should be selected
- *If no:* a system or equipment level M&V protocol should be used.

➡ ***Is energy use dependent upon weather?***

- *If yes:* a data-driven model approach should be selected.
- *If no:* go to the next step.

➡ ***Is energy use dependent upon another continuous variable?***

- *If yes:* a data-driven model approach should be selected.
- *If no:* a system or equipment level M&V protocol should be used.

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. Section 2.4.4.1 below provides a brief discussion on relative precision and helpful insights when using data-driven models.

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*.[13]

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?***

- *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

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

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.

2.4.4.1. Relative Precision in Modeling

The relative precision – or fractional savings uncertainty (FSU) – of an energy savings estimate is the magnitude of the uncertainty relative to the estimate of annual savings.[14] If a project is expected to save 300,000 kWh per year and the uncertainty – or margin of error – is ± 75,000 kWh/year, the relative precision of the estimate is ± 25%. The Verification by Energy Modeling and Verification by Energy Use Indexing protocols include guidance for calculating the expected uncertainty using baseline data. The key drivers of relative precision are:

1. **The size of the signal** – it is easier to precisely measure large effects than small effects. Savings uncertainty is not a function of expected savings, but the ability of the model to explain variation.
2. **Amount of noise in the data** – how much of the variation in energy consumption is explained by independent variables like weather or production? Savings from projects in facilities with noisy, or erratic, load patterns will be more uncertain than projects in facilities with more predictable load patterns.
3. **The frequency of the data** – the availability of daily or hourly data allows practitioners to fit better models of energy usage and explain more variation. This reduces uncertainty and can make Energy Modeling or Energy Indexing more viable options. Additional steps are required to produce unbiased estimates of uncertainty with high-frequency (hourly or sub-hourly) data because of the effects of autocorrelation on traditional statistical calculations.

M&V 2.0 is a trending topic within the energy efficiency industry that refers to the M&V opportunities afforded by access to high-frequency energy consumption data and the sophisticated modeling approaches that leverage this data.

Practitioners should be mindful of relative precision before making a final protocol selection. If the expected relative precision of a project savings estimate is greater than ± 50%, an alternative protocol should be considered. It is common to find uncomfortably high relative precision estimates for projects expected to save less than 5% of facility energy use. End-use metering can isolate the affected end-use(s) within a facility and significantly reduce the amount of noise in the data being modeled (without changing the size of the expected effect).

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[14] ASHRAE. 2014. *ASHRAE Guideline 14-2014 – Measurement of Energy, Demand, and Water Savings*. Atlanta, Ga.: American Society of Heating, Refrigerating and Air-Conditioning Engineers. https://www.techstreet.com/standards/guideline-14-2014-measurement-of-energy-demand-and-water-savings?product_id=1888937, sec. B4, p. 88 describes fractional savings uncertainty (FSU).

2.5. Protocol Selection Examples

In this section two projects previously completed by BPA utility customers are used to illustrate use of this selection guide. Each project had unique characteristics that were not typical and therefore straightforward applications of any of the M&V Protocols. The examples are provided to illustrate how the selection criteria were used to select the best M&V protocol for the project.

Example 1. Variable Frequency Drives on an Air Handling Unit Performing Below Code Requirements.[15]

An existing air handling unit served a public assembly space, and the owner planned to retrofit the AHU supply fans with variable frequency drives and demand-controlled ventilation controls. The AHU was still fully functional, but the amount of outside air provided was less than what current mechanical code required for new installations. Therefore, the planned introduction of additional outside air to bring the unit up to current ventilation standards increased the heating and cooling energy consumption relative to the existing condition.

The true baseline condition of an air handling unit delivering the required amount of ventilation air did not exist in the building, and therefore its energy use could not be measured. Although the amount of savings expected was far less than 200,000 kWh, the *Engineering Calculations with Verification Protocol* was not selected because current practice baseline fan loading and hours of operation could not be reliably quantified. The *Verification by Energy Modeling Protocol* could not be used because the baseline energy use was not reflective of current practice operation due to the fan insufficiently ventilating the space.

The *End Use Metering Absent Baseline Measurement Protocol* was chosen for this project since the energy savings was measured relative to an "absent baseline" scenario, i.e., with higher ventilation rates than the pre-installation existing condition. The key parameter of the AHU supply fan loading was verified through spot measurements for the constant speed fans (using current transducers), and the other parameter of operating hours was estimated based on site observations and interviews with facility personnel regarding system operation.

Example 2. Gymnasium Heating System Upgrade[16]

School district staff were considering upgrading a high school gymnasium's diesel-powered steam boiler heating and hot water system with either electrical-powered code-compliant resistance heating systems or two split system heat pump units and a packaged unit. The steam boiler served steam coils in air handling units, unit heaters, and unit ventilators in the gymnasium as well as two floors in the south section of the building. A pump-powered hot water loop circulated water through a conventional 50-gallon hot water heater and through a side-arm heat exchanger on the steam boiler. The hot water loop served the kitchen, bathrooms, and showers.

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[15] Contribution of this example from Natasha Houldson, Tacoma Power, is gratefully acknowledged. The original project narrative was edited to illustrate considerations in selecting a BPA M&V Protocol.

[16] Example provided courtesy of Ann DiNucci, BPA EE Energy Engineer, and Todd Munsey, Douglas Electric Cooperative. The original project narrative was edited to illustrate considerations in selecting a BPA M&V Protocol.

The proposed heat pumps and packaged unit had back-up heat consisting of electrical resistance heat strips, and demand-controlled ventilation controls. A 120-gallon water heater replaced the 50-gallon unit to assure hot water capacity met requirements for the gym's occupancy.

Recognizing the options of replacing the diesel-powered system with either a code-compliant electrical-resistance heating system or two split system heat pump units and a packaged unit, the project was ultimately not considered a fuel switching project, as the diesel-powered system would be replaced by the higher electrical energy efficiency system under consideration. Records of diesel purchases were available for the previous two years. An electric energy savings estimate of 104,000 kWh was generated: diesel fuel use was converted to electric energy use to create a hypothetical electric resistance code baseline, the baseline was adjusted by an estimated percentage of gymnasium fuel use and boiler efficiency, and electric energy savings were estimated by the difference between the baseline use and an estimated use of the new heat pumps and packaged units.

For savings less than 200,000 kWh, the Selection Guide offers the *Engineering Calculation with Verification Protocol* or the *Verification by Energy Modeling Protocol* as viable methods to verify savings for this project. Because the boiler was very old and failed to meet heating requirements and would be replaced by electric systems, no amount of rigor required to develop engineering calculations for a hypothetical baseline was considered sufficient to deliver a reliable estimate of savings. Because fuel use information was available, and could be measured in the post-installation period, the *Verification by Energy Modeling Protocol* was selected.

The Energy Modeling Protocol was implemented using the software tool ECAM, which is a whole building based analysis that compares pre- and post-installation actual utility energy data with respective actual local weather data using regression analysis. The pre- and post-installation regression models were normalized using long-term average weather. The post-installation performance period for this project was expected to be 6-9 months, which was anticipated to provide statistical results greater than a 50% fractional savings uncertainty (at an 80% confidence level). Should this threshold not be met, then the performance period was to be extended until the statistical significance requirement was considered appropriate by the reviewing BPA engineer. It was understood that no deemed measures (i.e. lighting, computer network management, etc.) would be implemented until the post-installation data collection was complete. If any deemed measures were installed in that time period, then all or a portion of the deemed energy savings would be subtracted from the whole building "gross" energy savings to determine the "net" savings from the projects' implemented measures.

3. Example M&V Plan

3.1. Overview

This section 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 facility upgrades often involve the installation of ECMs over an extended period, M&V plans provide the practitioner with a reminder as to the M&V protocol to implement, the post-installation M&V activities, and baseline definitions and calculations. 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*.

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

Assigned Personnel: ____________________ Date: ______________________________

Facility Name: ____

ECM Description: ______________________ BPA Protocol: End-Use Metering

3.2.1. 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. The factory experienced four days of maintenance downtime in the previous year. There were four paint booths within the shop, each with 60-hp constant speed fans.

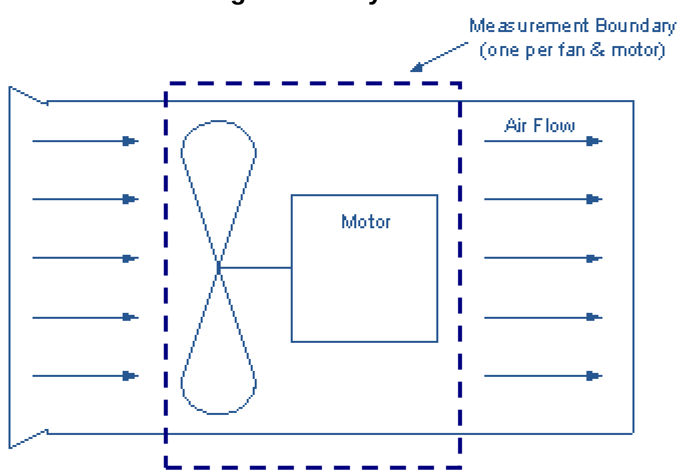
3.2.2. ECM Intent

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.

3.2.3. Measurement Boundary

The measurement boundary encompasses 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



3.2.4. BPA Protocol Selection

BPA's *End-Use Metering Protocol* will be employed for this project. 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.

3.2.5. 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.

3.2.6. 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's duration. In addition, the paint shop logs of cars entering and leaving the shop during the monitoring period will be obtained.

3.2.7. 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 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.

3.2.8. Responsibilities

Design and Implementation of M&V Plan:	Facility Access/Contact info:
Wilson Smith, P.E., XYZ Engineering Address: Email: Phone:	Rex Jones, Chief Engineer Address: Email: Phone:
ECM Project lead: Jane Doe, CEM, LEED AP Address: Email: Phone:	**Local Utility: Xenith PUD** Ron Potter, Account Manager Address: Email: Phone:

3.2.9. 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. 2014. *ASHRAE Guideline 14-2014 – Measurement of Energy, Demand, and Water Savings*. Atlanta, Ga.: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Purchase at: *https://www.techstreet.com/standards/guideline-14-2014-measurement-of-energy-demand-and-water-savings?product_id=1888937*

BPA. 2017. *2017-2019 Implementation Manual*. Portland, Ore.: Bonneville Power Administration, October 11, 2017.

Available at: *https://www.bpa.gov/EE/Policy/IManual/Documents/IM_2017_10-11-17.pdf*

IPMVP. 2012. *International Performance Measurement and Verification Protocol Volume I: Concepts and Options for Determining Energy and Water Savings*. EVO 10000 – 1:2012. Washington, D.C.: Efficiency Valuation Organization.

Available at: *https://evo-world.org/en/products-services-mainmenu-en/protocols/ipmvp*

Regional Technical Forum. 2011. UES Measures List, Standard Protocols, Calculators. Access available through BPA's webpage "Energy Efficiency Interim Solution 2.0 Files," which provides links to these resources.

Available at: *https://www.bpa.gov/EE/Policy/Solutions/Pages/default.aspx*.