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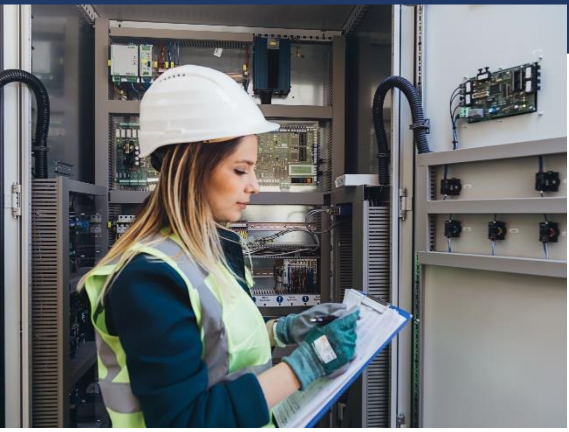
Measurement & Verification (M&V) Protocol Selection Guide and Example M&V Plan

September 2024



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

Version 3.1

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Prepared for

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1. Introduction

1.1. Purpose

This *Measurement & Verification (M&V) Protocol Selection Guide and Example M&V Plan* (*M&V Selection Guide)* aids in selecting the appropriate Bonneville Power Administration (BPA) M&V protocol, designing an M&V plan, and reporting savings. Originally developed in 2012, this *M&V 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 3 of this guide presents a framework for selecting the appropriate M&V protocol or guide to use for savings assurance, Section 4 provides guidance for minimum reporting requirements, and Section 5 presents an example M&V plan. Section 6 provides full citations (and web locations, where applicable) of documents referenced in this guide.

1.2. Protocols Version 3.0

BPA revised the M&V protocols described in this guide in 2024. BPA published the original documents in 2012 as Version 1.0, which were updated to Version 2.0 in 2018. The current guides are Version 3.0. This is Version 3.1 which includes updated Protocol Selection Examples in Section 2.4.

1.3. How is M&V Defined?

BPA's *Implementation Manual* (the IM) defines M&V 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: UES, savings calculators and custom projects.[3], Custom projects require site-specific*

1 2022-2023 Implementation Manual, BPA (IM), effective April 1, 2024. *https://www.bpa.gov/energy-and-services/efficiency/implementation-manual*

2 Power Act language summarized by BPA.

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

Measurement and Verification (M&V) to support reliable estimates of savings […][4] Custom projects require site-specific Measurement and Verification (M&V) to support reliable estimates of savings. For UES measures and Savings Calculators, measure specification and savings estimates must be RTF approved or BPA-Qualified. BPA M&V Protocols[5] direct M&V activities and are the reference documents for reliable M&V.[6]

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 Facility Energy Solutions to assist the organization in revising the M&V protocols used to assure reliable energy savings for the custom projects it accepts from its utility customers. The team conducted a detailed review of the 2018 M&V Protocols and developed the revised version 3.0 under Contract Number BPA-2-C-92283.

The Facility Energy Solutions team is comprised of:

- Facility Energy Solutions, led by Lia Webster, PE, CCP, CMVP
- Stillwater Energy, led by Anne Joiner, CMVP
- SBW Consulting, led by Santiago Rodríguez-Anderson

BPA's Todd Amundson, PE, CMVP, PMVE was project manager for the M&V protocol update work. The work included gathering feedback from BPA and regional stakeholders, and the team's own review to revise and update this 2024 *M&V Selection Guide*.

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 https://www.bpa.gov/-/media/Aep/energy-efficiency/document-library/24-25-im-april24-update.pdf, page 1.

5 Protocols include: M&V Protocol Selection Guide; reference guides for sampling, regression, and glossary; protocols on metering, engineering calculations with verification, energy modeling, and existing building commissioning.

6 https://www.bpa.gov/-/media/Aep/energy-efficiency/document-library/24-25-im-april24-update.pdf, page 1.

2. Protocol Selection Guidance

This *M&V 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 other documents in support of custom project M&V and the documents are listed Table 1. This table provides the document name and short-form name, a brief description of the document, and how the approaches align with the *International Performance Measurement and Verification Protocols* (IPMVP). The table is organized by IPMVP adherence and by type of document: Protocol, Application Guide, or Reference Guide.

Table 1: Overview of BPA's M&V Protocols and Guidance Documents

Document Name	Description and Applicability	IPMVP Adherence
BPA Fully IPMVP-Adherent Protocols (Comprehensive M&V)		
Verification by Equipment or End-Use Metering **(End-Use Metering)**	Intended for measures that change equipment loads or operating hours, or both loads and hours. Uses measurements of energy at equipment or end-use and of driving independent variable(s) Appropriate for non-interactive measures. Can address interactive measures in limited circumstances.	Adherent with IPMVP Option A and Option B
Verification by Meter-Based Energy Modeling **(Meter-Based Energy Modeling)**	Intended for measures involving equipment whose energy use is impacted by the measure(s) and by one or more independent variables not affected by the measure. Appropriate for interactive 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. Uses mathematical model of meter-based energy data & weather or other independent variable(s). 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 Option B and Option C
BPA Protocols for Conducting Engineering Calculations with Verification		
Engineering Calculations with Verification **(ECwV)**	Intended for projects with savings less than 400,000 kWh, or May be approved for projects for which other criteria dictate that an IPMVP-adherent protocol is not possible or not appropriate[7]. Uses baseline and post-installation site data and energy calculations to estimate energy savings. Simulation models may also be used (e.g., new construction).	Not adherent with IPMVP

[7] BPA engineering staff retains discretion as to whether a project with annual energy savings over 400,000 kWh may use this protocol and remain consistent with the IM requirements.

Document Name	Description and Applicability	IPMVP Adherence
BPA Protocol Application Guides		
Existing Building Commissioning	Intended for existing buildings with commissioning projects resulting in multiple measures with interactive effects between measures. This is a specific application of *Verification by Meter-Based Energy Modeling Protocol.*	Adherent with IPMVP Option B and Option C
Estimating Peak Demand Impacts	Provides guidance on the estimation of peak demand impacts. This application guide can be used in addition to one of the M&V protocols.	Depends on M&V Protocol used
BPA M&V Reference Guides		
Commercial & Industrial Strategic Energy Management (SEM) M&V	Intended for facilities participating in Strategic Energy Management (SEM) programs. Provides detailed guidance on using energy modeling in commercial and industrial SEM projects. This is a specific application of *Verification by Meter-Based Energy Modeling Protocol.*	Adherent with IPMVP Option B or Option C
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. Companion to *End-Use Metering* or *ECwV*.	Yes
Regression for M&V	Provides a simple explanation of regression modeling terms, principles, and methods. Companion to the *Energy Modeling* guide.	Not applicable
Glossary for M&V	Provides definitions of technical terms used in the guides.	Not applicable
M&V Protocol Selection Guide and Example M&V Plan **(M&V 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 applicable

2.1.1. Relationship Between M&V Documents

With multiple BPA M&V documents it may be helpful to note the relationships between them. As shown in Table 2, only three of these documents are BPA's 'M&V Protocols' which specify the M&V approaches available for BPA projects. The other documents are either 'Reference Guides' or 'Application Guides' which provide technical background or support specific applications when implementing an approach detailed in one of the M&V Protocols. The table below lists the 'Reference Guides' and 'Application Guides' which could be used with each M&V Protocol.

For example, *Verification by Energy Modeling Protocol* is the primary protocol addressing meter-based energy modeling (IPMVP Option C). Related documents include *C&I Strategic Energy Management (SEM) M&V Reference Guide* and *Existing Building Commissioning Protocol Application Guide* which cover specific applications using energy modeling. The M&V Regression Reference Guide provides additional technical background, and the Estimating Peak Demand Impacts Application Guide can be used with energy modeling if needed.

Table 2: Relationship Between BPA M&V Protocols & Guides

BPA M&V Protocol and Related Guides	General M&V Approach
Verification by Equipment or End-Use Metering Protocol	Uses energy measurements at equipment or end-use
*Estimating Peak Demand Impacts Application Guide**	
*Sampling for M&V: Reference Guide**	
Verification by Meter-Based Energy Modeling Protocol	Uses mathematical model of meter-based energy data & weather**
C&I Strategic Energy Management (SEM) M&V Reference Guide	
Existing Building Commissioning: Application Guide	
*M&V Regression Reference Guide**	
*Estimating Peak Demand Impacts Application Guide**	
Engineering Calculations with Verification Protocol (ECw/V)	Uses engineering calculations without energy measurements
*Estimating Peak Demand Impacts Application Guide**	
*Sampling for M&V: Reference Guide**	

* Note these Guides may apply to a number of protocols.
**weather or other independent variable

2.2. Considerations in Selecting an M&V Protocol

As a foundation for the specific protocol selection guidance in the next section, basic principles guiding the selection of a protocol appropriate for a given custom project are discussed below.

2.2.1. 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 energy savings achieved.

Potential to perform is defined as, and based on, whether the right equipment was installed and whether the equipment is operating properly and has the potential to save energy. 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 energy, however 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.

2.2.2. Determining The Project's Baseline

Perhaps the most challenging issue in conducting M&V activities is deciding what the energy use would have been in the absence of the project, which is the baseline energy. There is never absolute certainty when determining energy efficiency savings; M&V always requires making an estimate because the baseline conditions are non-existant once the project or measure has been installed.

So, in effect, one is always asking the question:

- → ***To what baseline are current energy use data compared****?* Different project circumstances require different baseline definitions. The choice is between an existing conditions baseline based on site conditions that existed prior to the implementation of the project or a standard industry practice / code-based baseline, discussed below.

The choice of baselines typically depends on the type of project or equipment purchase, which fall into three general categories:

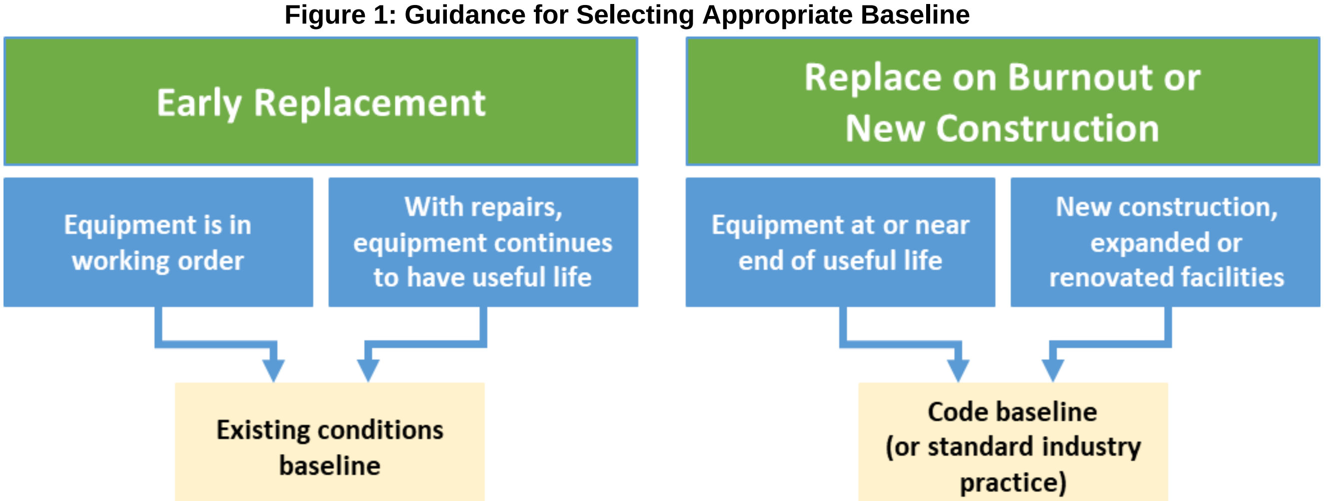
1. **Retrofits occurring before the end of the equipment's or system's useful life**. When the equipment replacement or system redesign occurs before the end of the equipment's or system's useful life are often called 'early replacement'. In these cases, the baseline is defined by the existing site conditions. Building owners commonly undertake optional retrofit projects when the expected energy and non-energy benefits (such as increased productivity, GHG reductions) 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 projects typically warrant existing baseline conditions, as those are the conditions that would prevail were the owner to take no action.

2. **Retrofits conducted when the equipment or system is at or near (within one year of) the end of its useful life**. Retrofits which occur at the end of equipment life are often called 'replace-on-burnout.' In these instances, the new equipment should meet any local or state code requirements. Where codes do not apply, the baseline used should be standard industry practice, which is the average efficiency of similar projects using current practices. The standard industry practice should be defined by M&V practitioner and set as the baseline for the project.

3. **New construction projects, including facility expansions or major renovations.** When the project requires new construction, a facility expansion or a major renovation, 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. This 'code' baseline is the alternate project based on the efficiency of equipment or systems required by code.

Figure 1 illustrates this guidance for selecting the appropriate baseline.

Figure 1: Guidance for Selecting Appropriate Baseline



2.2.3. Types of Baselines

Identifying the appropriate type of baseline for a project is a key step in determining the M&V process. The three types of baselines are applicable under different situations, described below.

Existing Conditions Baselines

An existing conditions baseline based on in situ conditions is typically used in projects which are:

- early replacement of functioning equipment for efficiency purposes,
- improvements to operations and maintenance practices,
- retro-commissioning efforts and control upgrades, or
- building envelope upgrades.

Code Baselines

A code baseline based on current applicable code requirements is used in projects which are:

- part of a new construction project that is subject to the requirements of current state and local building codes or federal standards,
- projects replacing equipment that is no longer operable or will need to be replaced within a year (i.e., replace on burnout),
- equipment that no longer meets user's needs, or
- equipment that must be replaced due to regulatory requirements, such as those by the U.S. Environmental Protection Agency (EPA).

BPA Custom Project program rules define new construction savings relative to "code" standards without defining those standards. The following websites provide information on mandates for new equipment and facilities among jurisdictions in the region.

Table 3: Resources for Regional Energy Codes

Organization	Website
Oregon Department of Energy	*https://www.oregon.gov/energy/energy-oregon/Pages/Energy-Code.aspx*
Washington State Building Code Council	*https://sbcc.wa.gov/state-codes-regulations-guidelines/state-building-code/energy-code*
Washington State University's Energy Program	*http://www.energy.wsu.edu/BuildingEfficiency/EnergyCode.aspx*
Northwest Energy Efficiency Alliance (NEEA)	*http://neea.org/initiativesour-work/codes-standards/codes*

The code in effect during the project's design phase is the relevant code during periods of code transition. Where local energy codes are more stringent than state codes, the local code establishes the baseline. The applicable code defines what would have been built in the absence of energy-efficient design.

Standard Industry Practice Baselines

A standard industry practice baseline based on current industry common practices is typically used in projects which are:

- replacing failed equipment, or
- installing a new process or expanding an existing process, or
- instances where a code baseline is required (listed above) but no energy code applies.

In such cases, there is typically no energy code that applies. The baseline should reflect the conditions that would have occurred in the absence of the project. For many applications, this is typically defined as the standard industry practice (equivalently, current practice).

Standard industry practice can be difficult to define. Publications can be useful for determining the practices that are common for an industry or system. Note, however, that articles tend to focus on new or innovative approaches. The standard practice is less likely to be highlighted.

The practices of the customer at other locations can be considered. If the customer uses different practices in jurisdictions that have incentives for energy efficiency than in other jurisdictions, this presents a strong basis for the standard practice. However, the customer may consistently exceed standard practice and, if so, the practitioner will need to look elsewhere to ascertain the standard industry practice. The practices of the customer’s competitors can be considered, but this information can be difficult to obtain. The practitioner may be able to make a case for standard practices as represented by the characteristics of commonly sold equipment, with the equipment identified or inferred from an investigation of manufacturer, distributor, and installer websites.

2.2.4. Data Collection and Costs

→ **Can reliable and sufficient pre- and post-installation measurements of energy use and any independent variables to which that energy use is related be obtained?**

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 safety considerations (e.g., travel, personal protective equipment, site policies) are met when the practitioner needs to visit the site to conduct direct measurements or install loggers. Safety policies of the governing organization must be followed.

Using on-site, sub-metered data collection systems can often provide the required data collection. Otherwise, on-site data collection activities can be expensive and may require multiple visits to set and retrieve instruments. These factors 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, relative to the savings potential and project incentives.

Alternately, the increased availability of utility meter-level energy data in daily or hourly intervals can provide a cost-effective alternative to sub-metering. Frequent allows practitioners to fit better models of energy usage and explain more variation when using Energy Modeling methods with less cost.

2.2.5. Other M&V Considerations

→ Are whole-building or system-level energy data available?

→ Are equipment-level energy measurements possible?

→ Are savings significant relative to overall building or site metered energy consumption (e.g., > 3%)?

→ Are building operations stable?

→ Can energy data and independent variables be accurately modeled? Is uncertainty in model less than expected energy savings?

These broad questions generate practical considerations about which M&V approach (protocol) is appropriate to use. 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.

2.2.6. Acceptable Level of Uncertainty in Savings

→ **How does the need for certainty in reported savings 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.

Although all savings contain some uncertainty, the level of rigor used in determining energy savings varies across M&V protocols and between projects. In general, measured energy data provides more accurate results than estimates (e.g., *Equipment or End-Use Metering Protocol* generally provides more accurate results than *ECwV Protocol*), but where one or more independent variables are considered, their relationship with energy use is paramount to the accuracy of the resulting estimates. The 'relative uncertainty' or standard error of these relationships can be compared to the expected savings to validate results (e.g., *Verification by Meter-Based Energy Modeling Protocol* includes guidance for calculating the expected uncertainty using baseline data so results can be validated).

In general, savings from projects in facilities with noisy, or erratic, load patterns will be more uncertain than projects in facilities with more predictable load patterns.

2.2.7. Qualifications of the M&V Practitioner

→ **Does the M&V practitioner have prior experience in conducting M&V, or a background in building science engineering or building modeling?** Ensure the practitioners' skills are sufficient to support the required M&V activities.

The practitioner should understand the IPMVP Options A, B, C, and D and the BPA M&V protocols. In addition, the practitioner might consider obtaining, but is not required to hold, an industry certification such as CMVP[8] or PMVA/PMVE[9].

2.3. M&V Protocol Selection Flow Chart

This guide discusses a range of potential M&V considerations which may drive the selection of an M&V approach. Discussions on the selection criteria relevant to a specific project can help all parties involved be aware of pertinent criteria impacting the M&V approach selected.

The user 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. Practitioners should comply with their organizations' safety policies, as well as those of the project site, and include safety as a discretionary factor in protocol selection. In some cases, an organization's safety policy may preclude the practitioner's use of 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: M&V Selection Flow Chart provides a flowchart for M&V protocol selection, which is described below.

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

The **middle portion**, shown in bright blue, represents custom measures for which the M&V plan may not *require* the use of pre-and post-installation energy measurements and instead recommend the less rigorous *Engineering Calculations with Verification (ECwV) Protocol*. New construction/major renovation projects may also consider using the *Equipment or End-Use Metering Protocol's* 'Absent Baseline Measurement approach'.

For retrofit projects, the flow chart shows when conditions merit use of the *Verification by Meter-Based Energy Modeling Protocol*, as this method is often cost effective to implement when data are available. This option may be implemented independently or along with the *ECwV Protocol*, if the listed criteria are met.

The **lower portion**, shown in dark blue, represents custom measures requiring comprehensive IPMVP-adherent protocols. These projects should have larger expected savings, generally above 400,000 kWh annually, so that the amount of savings justifies the effort and cost.

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8 CMVP is Certified Measurement and Verification Professional offered by Association of Energy Engineers.

9 PMVA/PMVE is Performance Measurement and Verification Analyst / Expert certification offered by Efficiency Valuation Organization (EVO).

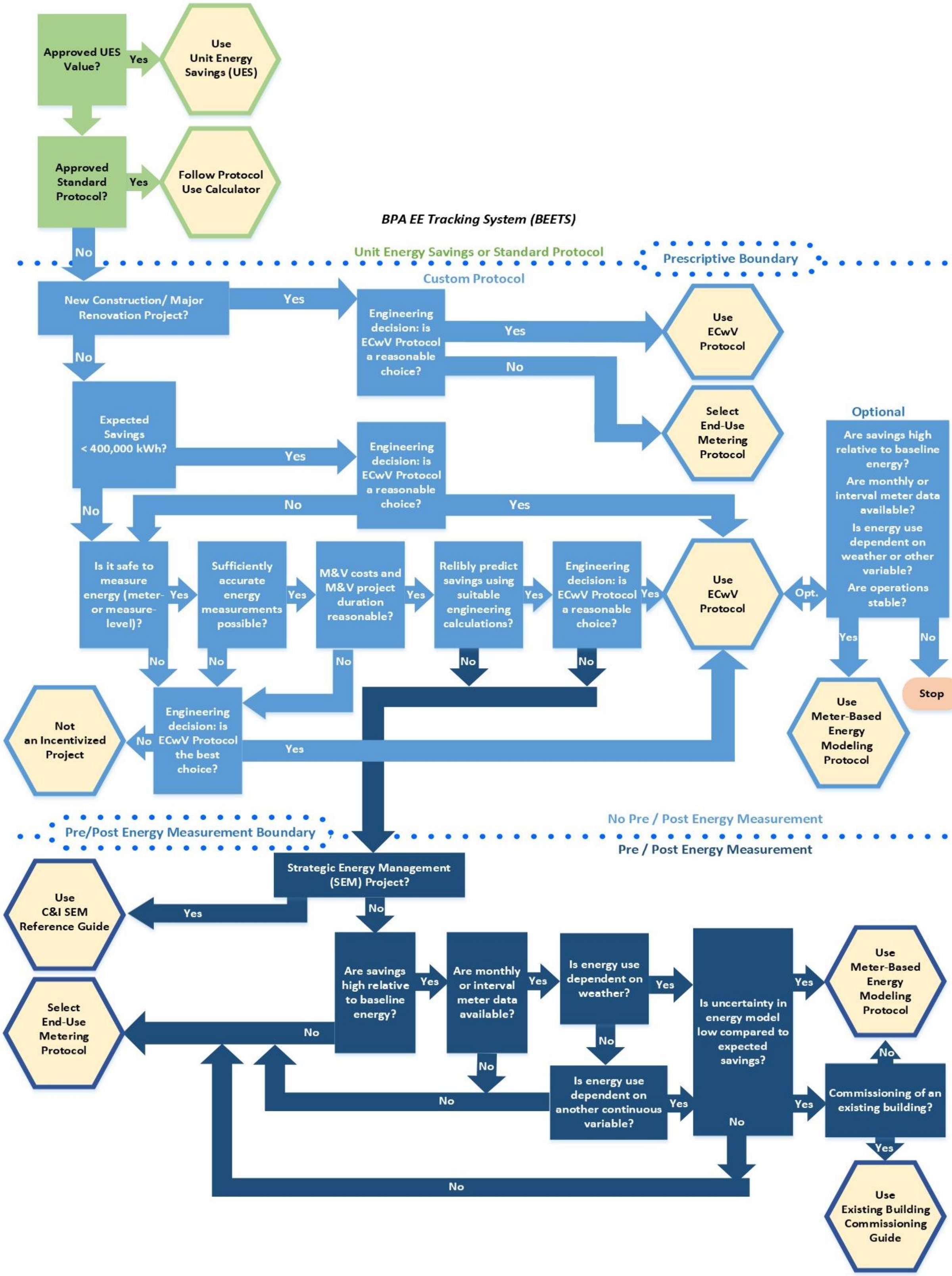

Figure 2-2: M&V Selection Flow Chart

Prescriptive projects are covered in the upper portion of the flow chart and comprise two types of measures:

- Unit Energy Savings - Measures whose savings do not vary by site but by population (e.g., customer sector, building type, and/or climate).
- Standard Protocol - Measures whose savings vary by site in an approved relationship with a simple operating characteristic, such as operating hours or motor nameplate horsepower.

The practitioner produces verified project savings for measures whose savings do not vary by site by verifying the number of units installed and key specifications of the installed equipment 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.[10]

Verified project savings for measures whose savings vary by site are produced by using a BPA-Qualified savings calculator or by following the RTF Standard Protocol and using the associated savings calculator. The calculators estimate project savings based on verified simple operating characteristics, such as run time, that drive the savings calculations. BPA's Energy Efficiency Tracking System (BEETS) webpage[11] provides links to Savings Calculators[12] which can also be accessed through BPA's Document Library.[13]

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

Other projects are considered 'Custom projects' which require a comprehensive M&V plan as indicated by the middle and lower portions of the flow chart (bright blue and dark blue). The M&V practitioner uses the criteria in the flow chart to assess the project. These criteria address the level of effort and rigor required for a project, and how project limitations (safety, cost, duration, etc.) influence the approach.

- For projects that are New Construction/Major Renovation, the practitioner decides if the use of energy simulation models included in *Engineering Calculations with Verification* (*ECwV*) is appropriate, or if *Verification by Equipment or End-Use Metering Protocol's* 'Absent Baseline Measurement approach' is a better fit for the project.
- For other types of projects, the next criteria is the level of energy savings expected.

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10 Information on UES Measures is available through Regional Technical Forum (*https://rtf.nwcouncil.org/measures/*) or BPA (*https://www.bpa.gov/energy-and-services/efficiency/bpa-energy-efficiency-tracking-system/beets-templates-and-tools*).

11 BPA's Energy Efficiency Tracking System (BEETS) webpage is *https://www.bpa.gov/energy-and-services/efficiency/bpa-energy-efficiency-tracking-system*

12 Information on Standard Protocols is available through the Regional Technical Forum *https://rtf.nwcouncil.org/standard-protocols/*

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

For projects with annual savings below 400,000 kWh, the M&V practitioner has the option of applying an *Engineering Calculations with Verification (ECwV)* approach. The practitioner can also use *ECwV* for projects that meet other criteria, 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 400,000 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.

In this second criteria set there is an option for the practitioner to choose the *Verification by Meter-Based Energy Modeling Protocol* as an alternate to or in addition to the *ECwV* approach. Implementing this method is contingent on whether the savings will be a significant fraction of annual baseline energy use, the availability of data from utility meters, and the dependence of energy use on weather and/or another continuous variable(s). With available tools such as ECAM along with utility and weather data, the energy modeling method is straightforward to implement, and may provide sufficient rigor.

For projects larger than the 400,000 -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 these projects 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. The basis for selecting the *ECwV* protocol for projects with expected savings over 400,000 kWh should be documented in the M&V plan or savings report for the project.

As shown in Figure 2-2: M&V Selection Flow Chart, if the initial savings estimate is less than 400,000 kWh annually, then the M&V practitioner can decide whether the *ECwV Protocol* is acceptable for the project. If the savings are greater than 400,000 kWh, or the analysts initially think engineering calculations are not acceptable, then one proceeds to answer additional questions.

→ If safe to measure energy (either meter-based or measure specific)?

- *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.

→ Are the savings over time expected to be consistent with an acceptable engineering calculation method available (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.

Additional Criteria for Selecting ECw/V

The following is a broader list of criteria suggested for determining whether *ECwV* or a more 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 small (less than 3% to 5%) 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 expected savings estimate** based on engineering calculations (and of 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 –** significant interactive effects necessitate comprehensive M&V.
- → **Are estimates of individual measure savings needed -** the ability to estimate individual measure savings differs among the protocols. The end-use metering approach can isolate the affected equipment/end-use(s) while this ability is limited in Meter-Based Energy Modeling applications.
- → **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.

2.3.2. 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 400,000 kWh where there are no applicable prescriptive project approaches, a BPA comprehensive protocol should be the default choice, with *ECwV* chosen only if there are compelling reasons approved by BPA.

The first decision box below the *Pre/Post Energy Measurement Boundary* in **Error! Reference source not found.** asks:

→ Is this a Strategic Energy Management (SEM) Project?

- *If yes*: an IPMVP Option C method detailed in the *C&I SEM Reference Guide* should be followed.
- *If no*: go to the next step.

→ Are savings high relative to baseline period energy use?

- *If yes:* go to the next step.
- *If no: Equipment or End-Use Metering Protocol* should be used, with the Absent Baseline Measurement approach used when baseline data is not available.

→ Are monthly or interval meter data available?

- *If yes:* go to the next step.
- *If no:* Select a system or equipment level M&V approach using *Equipment or End-Use Metering Protocol*.

→ Is energy use dependent upon weather?

- *If yes:* go to the next step.
- *If no:* Is energy use dependent upon another continuous variable?
    - *If yes*: go to the next step.
    - *If no*: a system or equipment level M&V approach following *Equipment or End-Use Metering Protocol* should be used.

→ Is uncertainty in the regression low compared to expected savings?

- *If yes:* a data-driven model approach should be selected following *Meter-Based Energy Modeling Protocol*.
- *If no:* a system or equipment level M&V approach following *Equipment or End-Use Metering Protocol* should be used.

→ Is the project the commissioning of an existing building?

- If yes: the *Existing Building Commissioning (EBCx) Application Guide* should be used.
- *If no:* use the *Meter-Based 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 the *Verification by Equipment or End-Use Metering Protocol* should be selected. The M&V practitioner should use the *Verification by Equipment or End-Use Metering Protocol* if a measured baseline is available and use the section on 'Absent Baseline Measurement' approach if the baseline cannot be measured. The Absent Baseline Measurement approach should be used for projects using a code-based or standard industry practice baseline (i.e., new construction or replace on burn-out).

Additional Considerations for Using Meter-Based Energy Models

There are four BPA M&V guides associated with data-driven energy models. Use of statistical models, rather than engineering models of physical systems, are the basis for these guides:

- *Verification by Meter-Based Energy Modeling Protocol,*
- *C&I Strategic Energy Management (SEM) M&V Reference Guide,*
- *Existing Building Commissioning: Application Guide, and*
- *M&V Regression Reference Guide.*

When considering using a data-driven model, the previous question regarding uncertainty in the regression compared to expected savings is a critical criterion:

→ Is uncertainty in the regression low compared to expected savings?

Practitioners should be mindful of uncertainty (i.e., relative precision or standard error/estimated savings) before making a final protocol selection based on energy data models. If the expected relative precision of a savings estimate is greater than ± 50%, an alternative protocol should be pursued. It is common to find uncomfortably high relative precision estimates for projects expected to save less than 3-5% of facility energy use.

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 ± 75,000/300,000 or ± 25%. The *Verification by Meter-Based Energy Modeling Protocol* includes guidance for calculating the expected uncertainty using baseline data. The key drivers of uncertainty (relative precision) are:

→ **Increased frequency of the energy data can improve results**. The availability of more frequent data (daily or hourly) allows practitioners to fit better models of energy usage and explain more variation. This reduces uncertainty and can make Energy Modeling more viable

→ **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.

→ **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.

2.4. 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. New Chiller Installed Exceeding Code Requirements

An air-cooled chiller serves the air handling units at an emergency care center that operates 24/hours every day. The existing chiller had unexpectedly failed and a temporary chiller was used until the new one was installed. Since the existing chiller is no longer functional, the new unit must meet local code requirements. ASHRAE 90.1 – 2022 was the code version in place at the time of the project which requires full load efficiency of about 1.2 kW/ton. The owner plans to install a unit that is more energy efficient than is required by code, and the new chiller selected has a full load efficiency of about 0.9 kW/ton, a 25% improvement in full load efficiency.

The baseline efficiency could be accurately estimated, but the system loads were unknown and could not be measured during the baseline period due to the short time line for the equipment to be installed. Although the amount of savings expected was far less than 400,000 kWh, the Engineering Calculations with Verification Protocol (ECwV) was not selected because baseline chiller loads and hours of operation could not be reliably estimated. The Verification by Energy Modeling Protocol could not be used because the expected level of savings were small (<2%) compared to building consumption.

The Verification by Equipment or End-Use Metering (EUM) Protocol's 'Absent Baseline Measurement' approach was chosen for this project since the energy savings need to be determined relative to an 'absent baseline' scenario (i.e., the post-installation operating conditions using code-minimum chiller efficiencies). Note this method requires spreadsheet calculations to determine baseline energy, similar to an ECwV method.

This equipment operates under a variable load and a variable schedule that are not impacted by the retrofit. Only the efficiency of the chiller is changed. The measure results in a change in efficiency, so that savings equation was selected from the EUM protocol: (kWhsaved = (Effbase - Effpost)*Loadpost*Hourspost).

The outdoor air temperatures and the chiller's cooling loads were quantified through control system trends (the supply and return chilled water temperatures, status (on/off) of the constant volume chilled water pumps) and the chilled water flow rate from the test and balance report. Data was collected for six weeks after the new chiller was installed and covered a wide range of operating conditions. Spot measurements of the new chiller's power consumption (kW) were made at the motor control center using a true RMS power meter. Measurements were taken under different conditions over several days.

Measured load data from the new chiller was correlated with outdoor air temperatures through regression analysis and a typical annual load profile (in ton-hours) was estimated using average annual weather for the project site. The measured kW was used to verify performance met manufacturer's specifications. The equipment manufacturer's performance data was used with this load profile to estimate the code-baseline chiller energy consumption. Energy use of the baseline and installed chillers were estimated using the measured load and the part load performance efficiencies of the units, and energy savings were the difference in the estimated energy use between the code-baseline and post-installation scenarios calculated using the selected savings equation, shown above. Final energy savings were 20,800 kWh / year.

Example 2. Gymnasium Heating System Upgrade[15]

School district staff were considering upgrading a high school gymnasium's existing heating system which includes a diesel-powered steam boiler serving steam heating coils in the air-handling units and unit heaters as well as a heat exchanger which served a 50-gallon domestic hot water system.

The choices for new heating systems were installing either electrical-powered code-compliant resistance heating systems or installing high-efficiency heat pumps (two split system heat pump units and a packaged heat pump unit). The proposed heat pumps and packaged unit had back-up heat consisting of electrical resistance heat strips, and the packaged unit included demand-controlled ventilation controls. A 120-gallon electric heat pump water heater was proposed to replaced the 50-gallon unit to assure hot water capacity met requirements for the gym's occupancy.

Records of diesel purchases and monthly consumption amounts were available for the previous two years. Since the existing equipment was antiquated and required replacement this project is considered an end of life equipment replacement that should use a code-compliant baseline.[16]

An initial electric energy savings estimate of 104,000 kWh per year was generated: the energy use of a hypothetical code baseline using electric resistance heat was estimated from the diesel fuel use (consumption was converted to electric energy use, then adjusted by an estimated boiler efficiency). The electric energy use of the heat pumps was estimated by dividing the code baseline consumption by the average efficiency improvement provided by the heat pumps based on improvement in heating seasonal performance factor (HSPF). The initial electrical energy savings was estimated as the difference between the baseline use and an use of the new heat pumps and packaged units.

[15] 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.

[16] Although this project changed the fuel used for the heating system, savings were not impacted by the fuel change and are eligible for BPA incentives. Energy savings from this project are based on replacing a code-compliant hypothetical baseline using resistance heat with higher efficiency heat pump units.

For projects saving less than 400,000 kWh, the M&V Selection Guide offers either the *Engineering Calculation with Verification Protocol* or the optional *Verification by Meter-Based Energy Modeling Protocol* as viable methods to verify savings for this project.

Because the measured energy use from a new dedicated electric meter would be available in the post-installation period and could be compared to the estimated code baseline energy use (described above) once adjusted to post-installation weather conditions, *Verification by Meter-Based Energy Modeling Protocol* was selected.

After completion, monthly energy use data on the new systems and weather data from the site were collected. After 3 months, a preliminary check on the results was made to ensure savings were apparent, Annual savings calculations were made after 12 months of data was collected. The *Verification by Meter-Based Energy Modeling Protocol* was implemented using the software tool ECAM, which is a whole building based analysis that compares baseline energy use and post-installation actual utility energy data with respective actual local weather data using regression analysis. Verified savings reported were 145,400 kWh/year.

No other projects were planned, and 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, nine of them – or slight variations on them – are included 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 proper execution of the project and orientation of new project personnel.

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

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

Assigned Personnel: _ Date: _

Facility Name: ________________

EEM Description: ___ BPA Protocol: End-Use Metering

3.2.1. Baseline Conditions

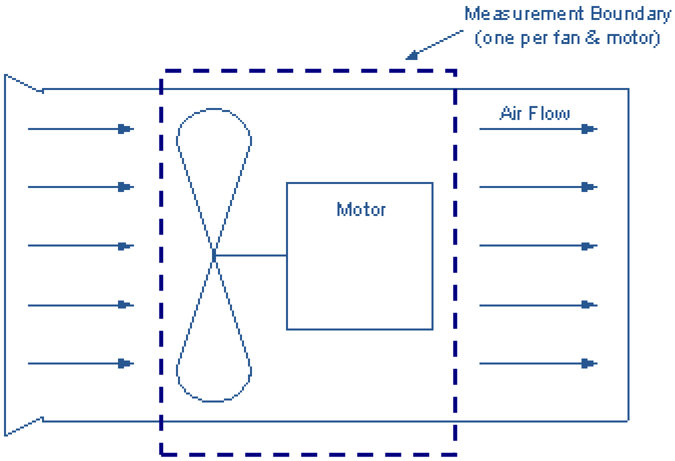
Exhaust fans in the paint shop at an automobile factory operated continuously throughout two 8-hour work shifts (6:00 am to midnight) during each work week. The factory experienced four days of maintenance downtime in the previous year. There were four paint booths within the shop, each with 60-hp constant 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 based on VOC 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 EEM was to reduce the hours of operation.



3.2.4. BPA Protocol Selection

BPA's *Verification by Equipment or 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 used when operating will be verified that it is unchanged, using a spot measurement of fan motor power. The new controls will be tested on-site to ensure the potential to perform and will turn the fan on & off when the VOC threshold setpoint is exceeded.

Each exhaust fan's runtime 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 *Verification by Equipment of 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.

Since operating conditions for the fans do not change, 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 or amp loggers on each exhaust fan.

In the post-installation period, a metric for 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 *Verification by Equipment or End-Use Metering Protocol*:

$$kWh_{saved} = kW_{base} \cdot HRS_{base} - kW_{base} \sum_{i} HRS_{post,i}$$

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: **Wilson Smith, P.E., XYZ Engineering** **Address:** **Email:** **Phone:**	**Facility Access/Contact info:** **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 month and expected per year
- → Notes on data sources, data cleaning, and data issues

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 EEM and its effect on operation hours, provide reference to the M&V Plan, and note any changes. The relevant BPA M&V protocol (i.e., *Verification by Equipment or End-Use Metering*) will be cited and calculations summarized, and savings results clearly labeled.

4. References and Resources

BPA. 2024. *2024-2025 Implementation Manual*. Portland, Or: Bonneville Power Administration, April 1, 2024.

Available at: *https://www.bpa.gov/-/media/Aep/energy-efficiency/document-library/24-25-RP-IM.pdf*

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

Regional Technical Forum (RTF). 2023. UES Measures List, Standard Protocols, Calculators. Available at:

UES Measures: *https://rtf.nwcouncil.org/measures/*

Standard Protocols: https://rtf.nwcouncil.org/standard-protocols/

Calculators: *https://www.bpa.gov/energy-and-services/efficiency/bpa-energy-efficiency-tracking-system/beets-templates-and-tools*