BPA's
Custom Project M&V Protocols Update

October 10, 2024

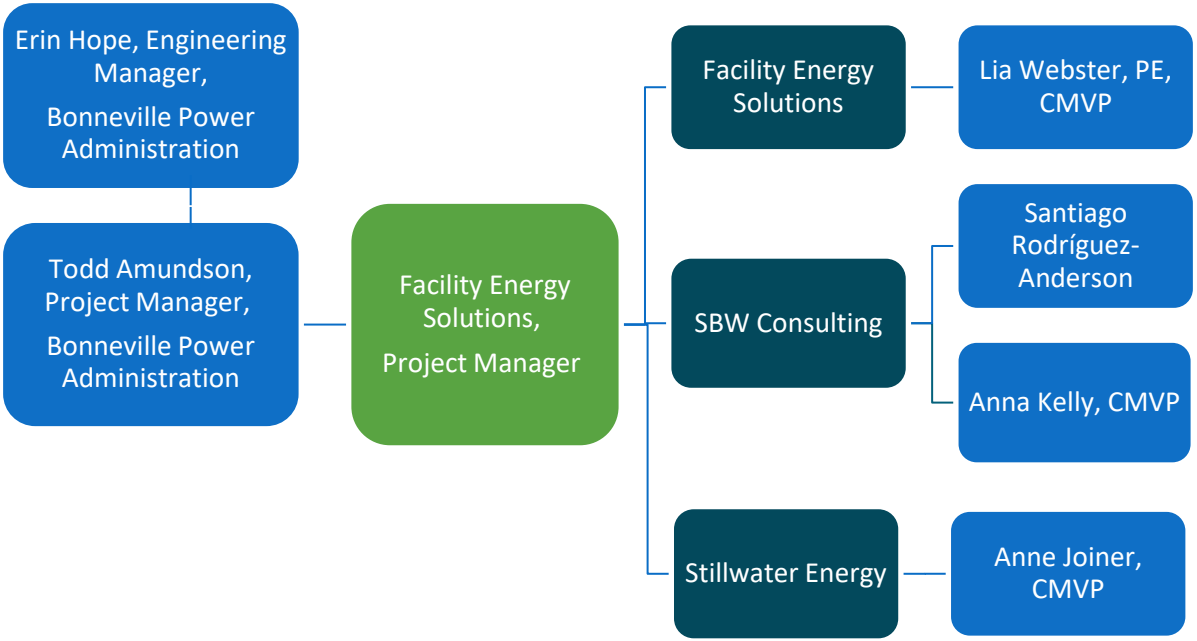
Questions or comments as we go

Use Chat in Webex

or

Raise Hand

Team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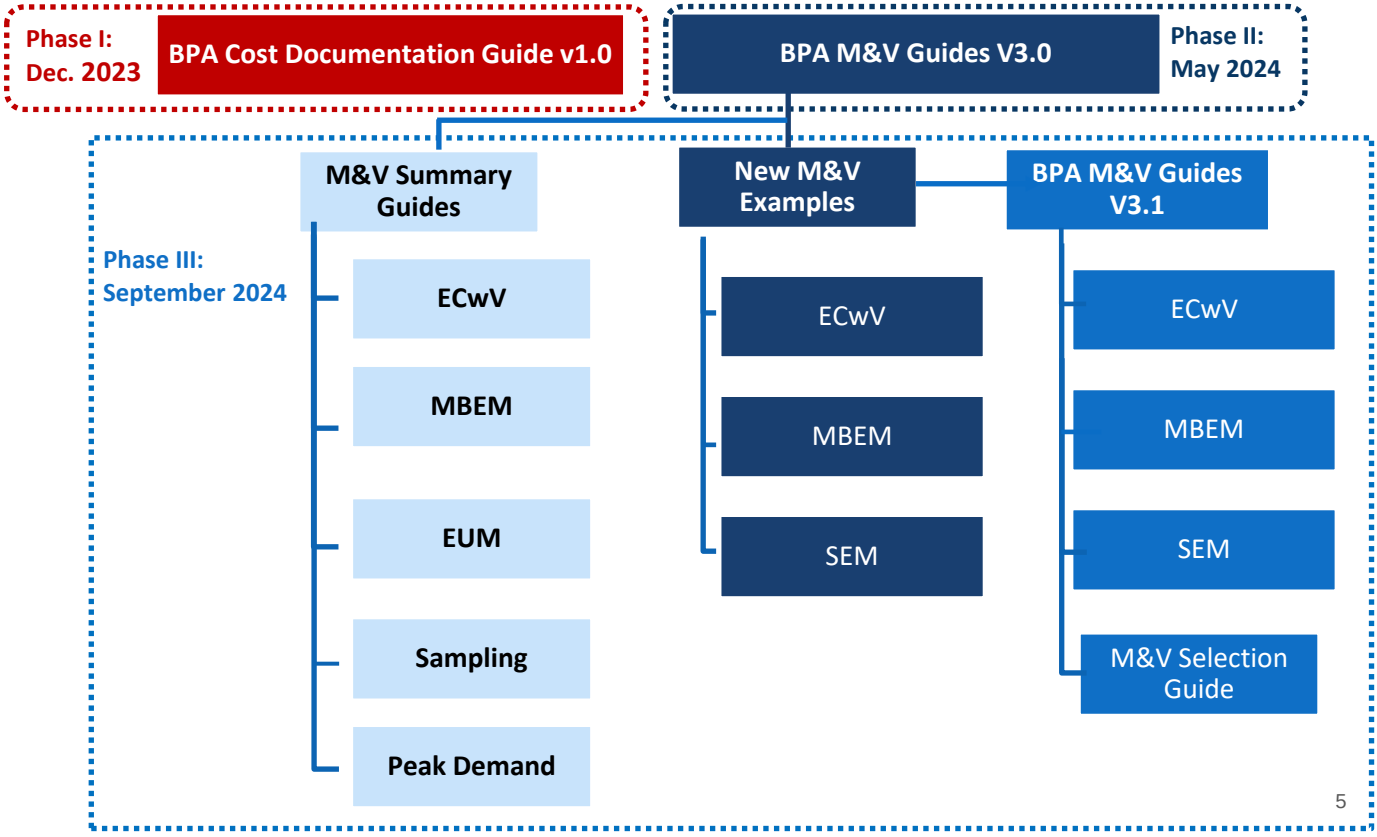
Anna Kelly, CMVP
Stillwater Energy
Anne Joiner, CMVP

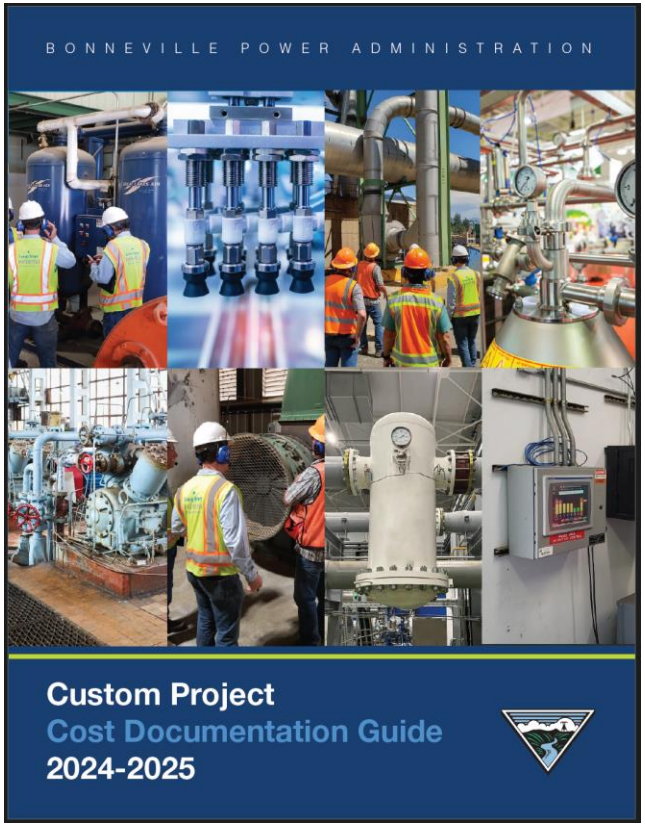
Project Overview



BPA's Cost Documentation Guide

Custom Project Cost Documenation Guide

- Completed December 2023
- Defines project costs eligible for incentives
- Details supporting documentation required
- Specifies cost impacts needed for cost effectiveness calcs

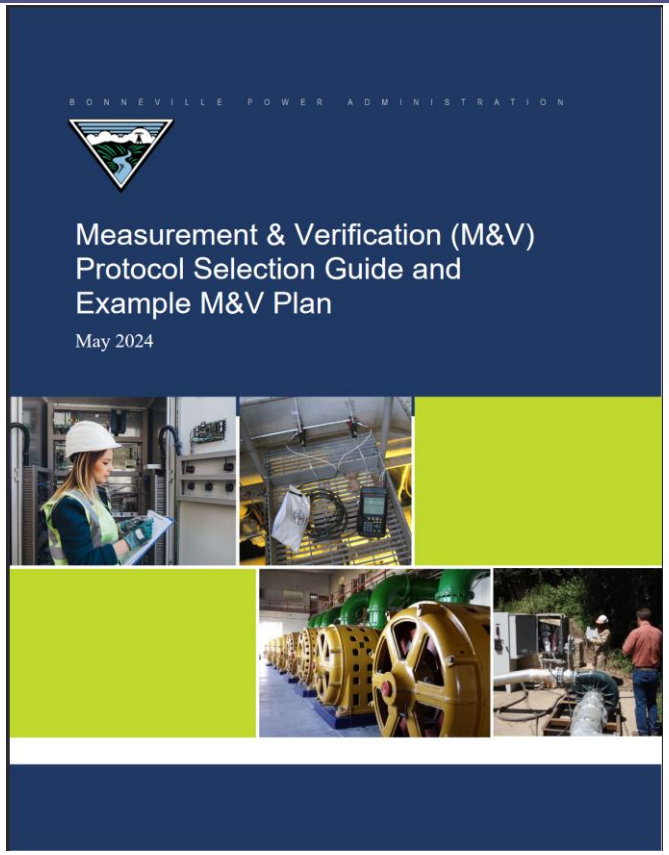


M&V Guides V3.0

M&V Guides V3.0

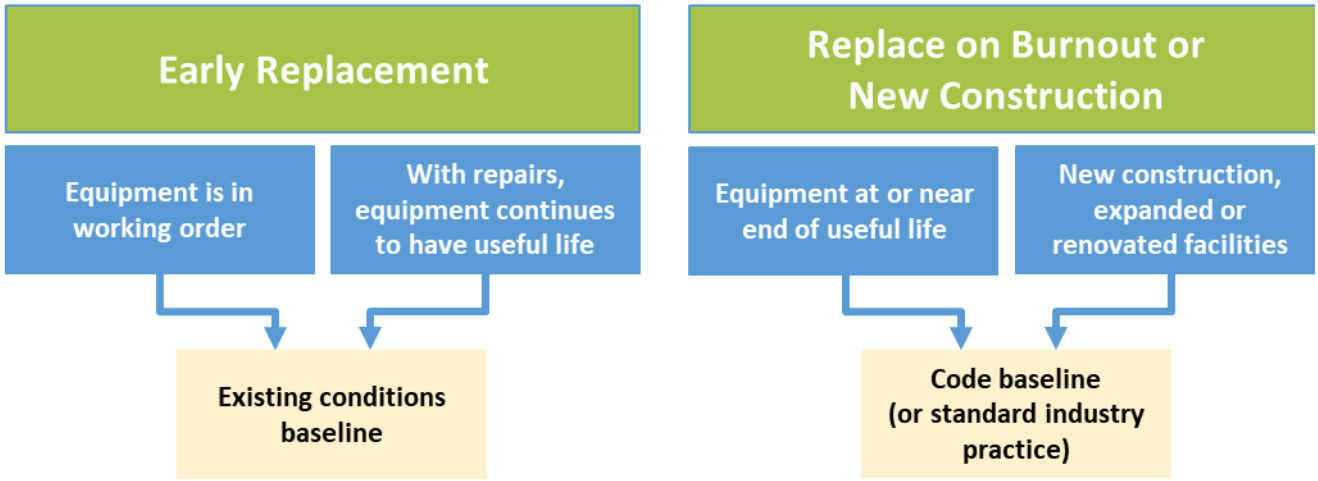
M&V Protocol Selection Guide and Example M&V Plan

- Overview of M&V Protocols
- General guidance on M&V
- Types of baselines
- M&V Protocol Selection flow-chart
- Examples of protocol selection
- M&V Plan example

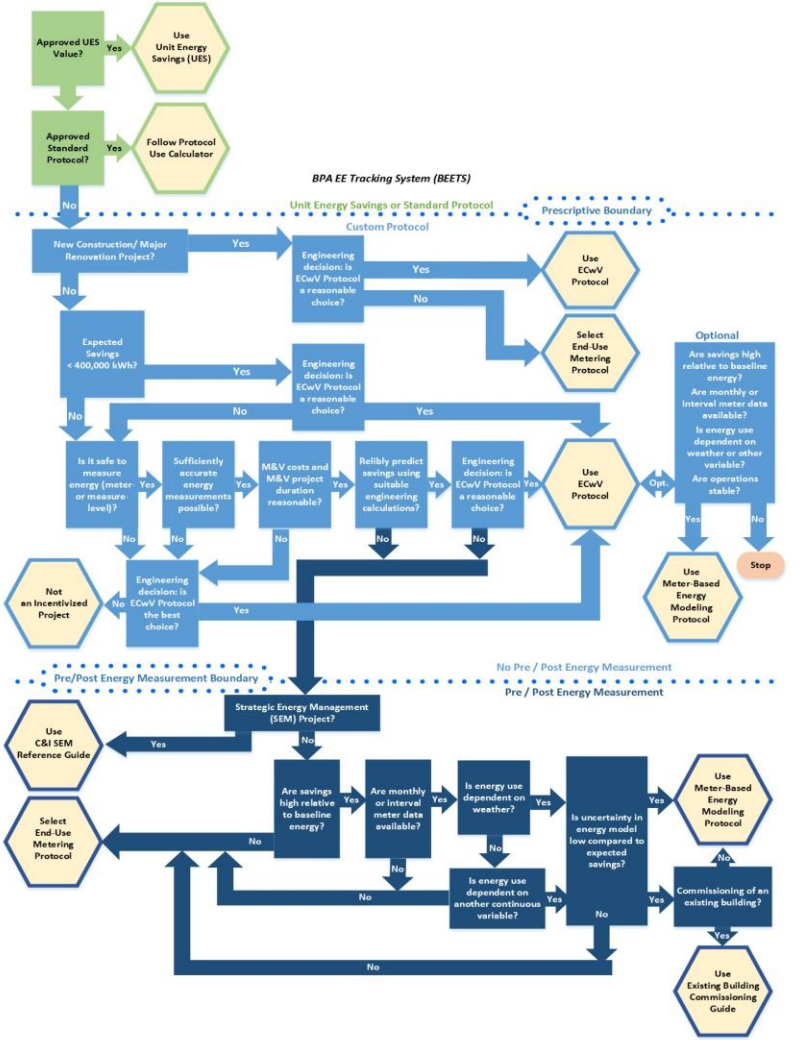


M&V Protocol Selection Guide

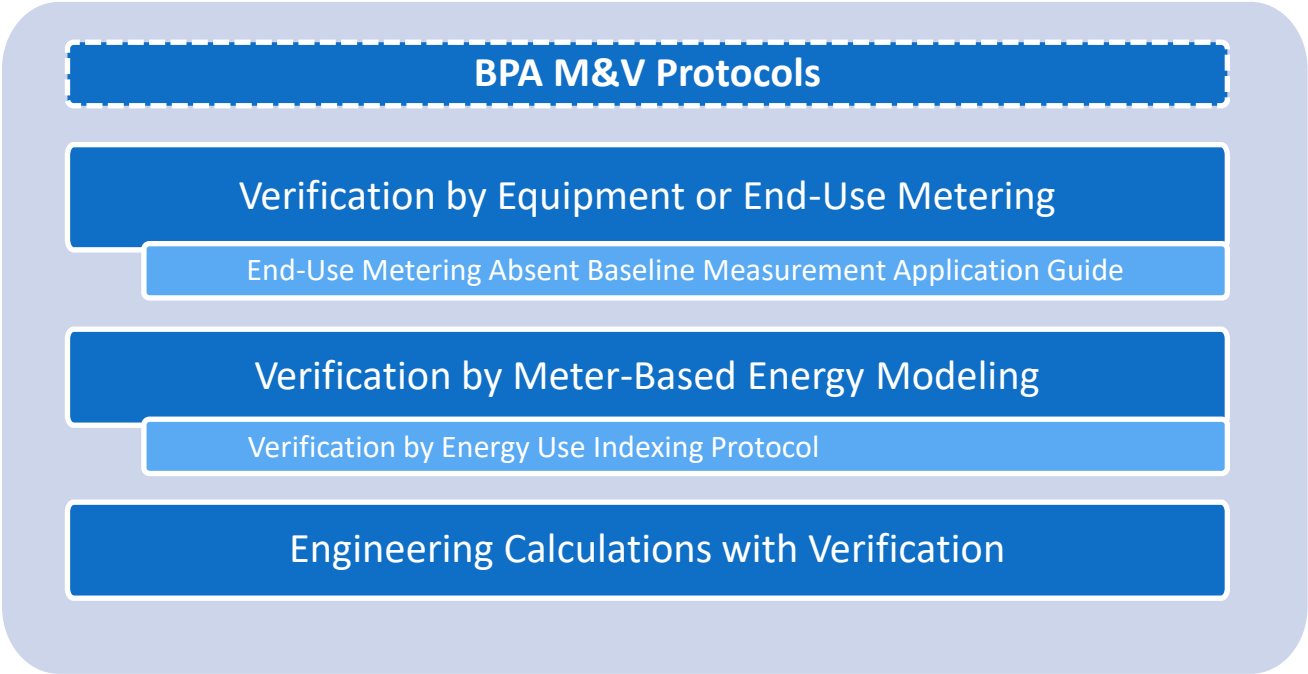
Baseline Selection



M&V Protocol Selection



BPA M&V Protocols & Guides V 3.0 Integrated Documents



BPA M&V Protocols & Guides V3.0

M&V Protocol Selection Guide and Example M&V Plan

Verification by Equipment or End-Use Metering Protocol

Verification by Meter-Based Energy Modeling Protocol

- M&V Regression Reference Guide
- Existing Building Commissioning Protocol Application Guide
- C&I Strategic Energy Management M&V Reference Guide

Engineering Calculations with Verification Protocol

- Estimating Peak Demand Impacts Application Guide
- Sampling for M&V Reference Guide
- Glossary for M&V

Custom M&V Protocols Update 2024

New Example Projects

Updating M&V Examples

- Assessed all existing M&V examples (14)
- Identified examples to update or replace (3)
  - Selection Guide
  - ECwV
- Strategically add examples
  - Ensure coverage of M&V methods
- Reviewed and selected recently completed BPA projects
- Developed new examples (7 total)
  - Some methods reflect improvements over actual project

7 New or Updated M&V Examples

M&V Protocol Selection Guide and Example M&V Plan

- Example 1. New Chiller Installed Exceeding Code Requirements
- Example 2. Gymnasium Heating System Upgrade

Engineering Calculations with Verification (ECwV)

- Example #1: Engineering Calculations Using a Publicly Available Software Tool
- Example #3: Engineering Calculations Using a Vendor Supplied Software Tool
- Example #4: Engineering Calculations Using a Custom Spreadsheet

Verification by Meter-Based Energy Modeling Protocol

- Example of Meter-Based Energy Modeling for a System

C&I Strategic Energy Management M&V Reference Guide

- Commercial SEM Example

7 New or Updated M&V Examples

M&V Protocol Selection Guide and Example M&V Plan

Example 1. New Chiller Installed Exceeding Code Requirements

Scope

- Full failure of an existing chiller
- Installs a new chiller with high efficiency rating

M&V Approach

- Equipment or End-Use Metering (EUM) Protocol's 'Absent Baseline'

Key Elements

- MBEM & ECwV are not selected
- Uses code required equipment for baseline
- Adjusts estimated baseline using post-installation loads

7 New or Updated M&V Examples

M&V Protocol Selection Guide and Example M&V Plan

Example 2. Gymnasium Heating System Upgrade

Scope

- Removal of diesel boiler and hydronic heating system
- Installation of heat pumps

M&V Approach

- Verification by Meter-Based Energy Modeling

Key Elements

- EUM & ECwV are not selected
- Uses code required minimum efficiency for baseline
- Demonstrates electrification project (not fuel switching)

7 New or Updated M&V Examples

Engineering Calculations with Verification (ECwV)

Example #1: Engineering Calculations Using a Publicly Available Software Tool

Scope

- New air compressor installed in industrial facility with additional capacity

M&V Approach

- Engineering Calculations Using a Publicly Available Software Tool (NWRCAT)

Key Elements

- Uses measured field data in calculations
- Adjusts baseline energy using post-install load data
- Provides adequate detail on software inputs and outputs

7 New or Updated M&V Examples

Engineering Calculations with Verification (ECwV)

Example #3: Engineering Calculations Using a Vendor Supplied Software Tool

Scope
- New fast-acting doors at refrigerated warehouse

M&V Approach
- Engineering Calculations Using a Proprietary Software Tool
  - Models refrigeration system, loads from doors pre- and post-

Key Elements
- Uses a proprietary calculation tool
- Provides adequate detail on software inputs and outputs
- Demonstrates good field verification

7 New or Updated M&V Examples

Engineering Calculations with Verification (ECwV)

Example #4: Engineering Calculations Using a Custom Spreadsheet

Scope

- New process to supply fuel to cogeneration boiler when sawmill is off

M&V Approach

- Engineering Calculations Using a custom spreadsheet

Key Elements

- Uses measured data and estimated values in calculations
- Provides appropriate level of technical detail

7 New or Updated M&V Examples

Verification by Meter-Based Energy Modeling Protocol

Example of Meter-Based Energy Modeling for a System

Scope

- New high-performance condenser for cold storage facility

M&V Approach

- Verification by Meter-Based Energy Modeling for a system
  - Uses sub-metered power data from compressor and fan power from condenser

Key Elements

- Demonstrates system-level energy modeling
- Uses TMY data (wet bulb) to normalize models
- Includes detailed uncertainty calculations

7 New or Updated M&V Examples

C&I Strategic Energy Management M&V Reference Guide

Example of Meter-Based Energy Modeling for SEM

Scope

- SEM Program participation for commercial office building
  - Energy management and O&M

M&V Approach

- Verification by MBEM using SEM Guide
  - Tracks energy savings over time

Key Elements

- Uses daily HDD65/day data for monthly models
- Shows savings accumulation over time (CUSUM)
- Monthly data adjusted to account for irregular time intervals in data
- Demonstrates adjusting for other incentivized projects

Protocol Updates

Updates to Guides V3.1

M&V Protocol Selection Guide and Example M&V Plan

- Example 1. New Chiller Installed Exceeding Code Requirements
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Engineering Calculations with Verification (ECwV) Protocol

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Verification by Meter-Based Energy Modeling Protocol

- Example of Meter-Based Energy Modeling for a System

C&I Strategic Energy Management M&V Reference Guide

- Commercial SEM Example

BONNEVILLE POWER ADMINISTRATION

Verification by Meter-Based Energy Modeling Protocol

September 2024

BONNEVILLE POWER ADMINISTRATION

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

September 2024

BONNEVILLE POWER ADMINISTRATION

Engineering Calculations with Verification Protocol

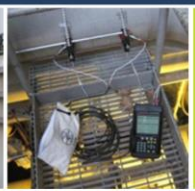
September 2024




BONNEVILLE POWER ADMINISTRATION

Commercial & Industrial SEM M&V Reference Guide

September 2024

M&V Summary Guides

BPA M&V Summary Guides

- Purpose
  - Provide an overview of selected BPA M&V Protocol or Guide
  - Help users understand BPA's M&V methods

- Approach
  - Summarizes M&V protocol or guide
  - 2 to 4 pages
  - Provides an overview of the M&V procedure
  - Includes 'When to Use', 'When Not to Use'
  - Provides links to related BPA documents and other resources
  - Highlights examples included

- Result
  - 5 Summary Guides:
    - ECwV, EUM, MBEM, Sampling for M&V, Peak Demand Impacts

BPA M&V Protocols & Guides V3.0 / V3.1

M&V Protocol Selection Guide and Example M&V Plan

Verification by Equipment or End-Use Metering Protocol

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BPA M&V Summary Guides

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SUMMARY GUIDE:
Sampling for M&V: Reference Guide
SUMMARY GUIDE:
Estimating Peak Demand Impacts
SUMMARY GUIDE:
Equipment or End-Use Metering Protocol
SUMMARY GUIDE:
Meter-Based Energy Modeling Protocol
SUMMARY GUIDE:
Engineering Calculations with Verification Protocol
BONNEVILLE POWER ADMINISTRATION
OVERVIEW
Bonneville Power Administration's (BPA) Engineering Calculations with Verification Protocol (ECwV) uses engineering algorithms to estimate baseline and post-installation energy use of equipment, systems, or buildings. Savings are the difference in estimated electricity consumption between the baseline and post-installation scenarios.
Engineering calculations:
Are either developed in spreadsheets (e.g., Excel) or in energy simulation modeling software (e.g., eQUEST)
Are based on the physics of systems
Do not require measured energy use
Require field verification and true up of calculations
Accuracy of savings estimates can vary and depend on data and assumptions used
Are intended for use on smaller projects
WHEN TO USE

SUMMARY GUIDE:

Engineering Calculations with Verification Protocol

BONNEVILLE POWER ADMINISTRATION

OVERVIEW

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- Are based on the physics of systems
- Do not require measured energy use
- Require field verification and true up of calculations
- Accuracy of savings estimates can vary and depend on data and assumptions used
- Are intended for use on smaller projects

WHEN TO USE

- Measures saving less than 400,000 kwh/yr
- New construction / major renovations
- Retrofit or replacement of existing equipment
- Equipment and system operations are well understood
  - Values of key operating parameters
  - The relationship of important variables to other driving variables
- The measure's impacts on the system are well understood
- Knowledge of the system to which the measure applies
- Knowledge of the physics underpinning how the measure saves energy
- Equipment-level energy measurements are not feasible

WHEN NOT TO USE

- Physics of system performance are not clearly defined
- Operational details of system or equipment are not documented

PROCEDURE

Collect Data

Step 1: Describe the process and energy efficiency measure:

- Baseline conditions
- Post-installation conditions

Gather project related data:

- Existing and new system design and specifications
- Operational data

Pre-Installation

Step 2: Establish baseline annual energy use (kWh / year)

- Use existing or code conditions

Step 3: Estimate post-installation annual energy use (kWh/year)

Step 4: Calculate energy savings (kWh/year)

Post-Installation

Step 5: Measure verification

- Inspections, measurements, functional testing, trend logs

Step 6: Adjust estimated energy savings

- True up assumptions

REPORTING REQUIREMENTS

- Detailed descriptions of the project and efficiency measures. The description(s) should contain:
  - Sufficient detail to clearly understand the processes involved
  - The proposed savings measure details
  - How the measure will achieve the stated savings
- Detailed energy savings calculations should include:
  - Step by step descriptions
  - Details of the data used
  - Input and output details from software simulations
- Documentation may include pictures, field notes, equipment specifications, vendor quotes, calculation files, and written reports

TIPS

- Use accepted algorithms or well known software
- Annotate assumptions and equations used
- Conduct spot measurements or use available trend data
- Use equipment specifications (e.g., pump & fan curves, manufacturer specifications)
- Double check work!

TOOLS & RESOURCES

- **Weather Data:** NREL's TMY3 Weather Data
- **Software Tools:** Energy Plus, EQuest, ECAM, DOE software tools
- **Guidelines:** IPMVP, state building energy codes (OR, WA), ASHRAE, AHRI

APPLICATION SPECIFIC CONSIDERATIONS

Within the ECwV Protocol there are two calculation approaches considered:spreadsheet based engineering calculations and simulation models. Each approach has some specific requirements and considerations summarized below.

	SPREADSHEET CALCULATIONS	SIMULATION MODELS
Overview	Engineering estimates of system or equipment energy use are developed for the baseline and post-installation scenarios.	Software models of a system or whole building are developed to estimate energy use for the baseline and post-installation scenarios.
Analysis	Calculations made in spreadsheets (e.g., Excel) based on hourly analyses or annual temperature bins (8,760 hours).	Software simulating a whole-building (e.g., EnergyPlus, DOE-2 / eQUEST) or of system-level (e.g., pump tool) is used.
Use Cases	• Use for equipment or system-level retrofit or replacement projects in existing facilities • Correlations in site-specific operations and independent variables can be developed • Savings originate from a single piece of equipment or system • Savings are largely from controls changes • Method and data to calculate savings is available	• Use for new construction or major renovation projects • Correlations to real data cannot be developed • Measures affecting envelope loads or with other complex interactions • A simulation model already exists • Zone loads need to be estimated
Approach	Equipment level estimates of energy use based on known engineering relationships (e.g., air flow vs. fan speed, efficiency vs load) and site specific system data.	Building or system-level estimates of loads and energy use based on engineering relationships (e.g., air flow vs. fan speed, efficiency vs load) are used with site specific system data.
Savings	Savings are the difference in estimated electricity consumption between baseline and post-installation scenarios.	One simulation model is developed (e.g., baseline) and then modified to represent the change in conditions (e.g., post-installation).

EXAMPLES OF ENGINEERING CALCULATIONS

The ECwV Protocol includes four examples of how the protocol is applied to different types of energy savings projects.

Example 1

Scope:
New air compressor and dryer with increased capacity

M&V Approach:
Engineering Calculations using a publicly available software tool

Reference:
ECwV pg. 53

Example 2

Scope:
New windows and HVAC system at an elementary school.

M&V Approach:
Simulation Approach for an Existing Building using eQuest

Reference:
ECwV pg. 58

Example 3

Scope:
Installation of high speed rollup doors.

M&V Approach:
Engineering Calculations using a vendor supplied software tool

Reference:
ECwV pg. 61

Example 4

Scope:
More efficient configuration of conveyor systems

M&V Approach:
Engineering Calculations using a custom spreadsheet

Reference:
ECwV pg. 70

BPA RESOURCES

BPA Measurement and Verification Resource Library

Engineering Calculations with Verification Protocol

M&V Protocol Selection Guide and Example M&V Plan

SUMMARY GUIDE:

Equipment or End-Use Metering Protocol

BONNEVILLE POWER ADMINISTRATION

OVERVIEW

Bonneville Power Adminstration's (BPA) *Verification by Equipment or End-Use Metering Protocol* (EUM) is used for measures that impact isolated equipment or systems and uses monitored energy use and/or other parameters in the baseline and post-installation scenarios. Savings are determined from defined equations based on loads and hours of use in the baseline and post-installation scenarios.

End-Use Metering:

- Energy use characteristics of load and hours of use are defined for baseline and post-installation scenarios
- System or equipment-level parameters are monitored
- Measured energy and operational data are used
- Can use code defined or existing baseline conditions
- Requires field verification and true up of baseline conditions
- Allows for a range of accuracy depending on data used

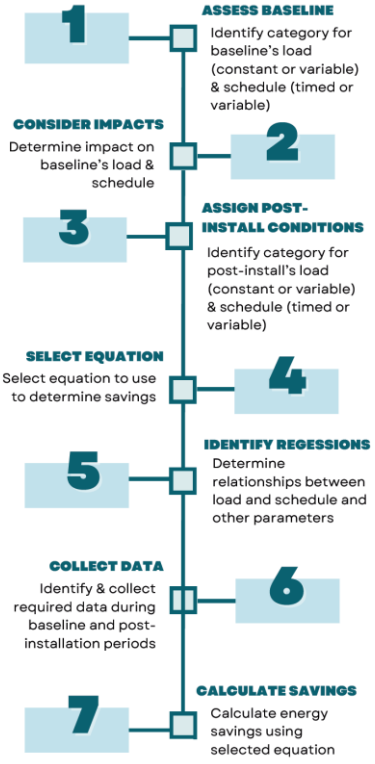
WHEN TO USE

- Measures that impact stand alone equipment or systems (e.g., fans, pumps, motors, lighting, chillers, and boilers)
- Equipment and system operations can be monitored
- Retrofit or replacement of existing equipment
- Can apply to end of life or early replacement projects
- Where equipment or system loads and schedules can be monitored or determined from other data

WHEN NOT TO USE

- Measures involving multiple pieces of equipment with complex interactions
- Projects with significant interactive effects
- Where equipment or system level measurements are not feasible
- Metering period(s) are too short to reflect full range of operations
- Projects with random loads or schedules

PROCEDURE



REPORTING REQUIREMENTS

- Data for the baseline and reporting periods
- Load and schedule for baseline and reporting periods
  - include sources of data along with necessary data correlations and proxies applied
- The savings equation used
- Operational verification results

TIPS

- Use measured energy and operational data to establish loads and hours of use
- Use the 'Absent Baseline' approach when a code compliant or standard practice baseline is required
- Level of rigor can vary based on the measurements included
- Measure power (kW) when possible and can be done safely
- Develop equations from measurements to characterize variable loads
- Equipment specifications may be used with operating data to determine loads
- Use 'bins' to group data (e.g., hours at a range of temperatures)
- Loads and hours of use from post-installation period can apply to the baseline if unchanged

TOOLS & RESOURCES

- ASHRAE Guideline 14-2014 Annex E for Retrofit Isolation Approach Techniques
- State building energy codes (OR, WA)

APPLICATION SPECIFIC CONSIDERATIONS

Within the EUM Protocol there are two calculation approaches considered: end-use metering and end-use metering absent baseline. Each approach has some specific requirements and considerations summarized below.

	END-USE METERING APPROACH	END-USE METERING ABSENT BASELINE APPROACH
Overview	Savings are determined from monitored data (energy use and operational parameters) in baseline and post-installation periods on isolated equipment or end-use.	Savings are determined from monitored post-installation data (energy use and operational parameters) from isolated equipment or end-use. Post-installation data and code-specified parameters are used to determine baseline energy use.
Approach	Energy use characteristics of the equipment are broken down into load and hours of use components, and whether these components are constant or variable in baseline and in post-installation periods.	
Analysis	Measured load and operating data from the baseline and post-installation are analyzed. Regression analysis can be used to extrapolate measured data to a full year.	Measured load and operating data from the post-installation are used with code requirements to determine baseline loads and hours of use. Regression analysis can be used to extrapolate measured data to a full year.
Use Cases	• Early replacement of equipment in existing buildings • Monitoring equipment exists or temporary loggers can be added	• End of life equipment replacements in existing buildings • Targeted efficiency improvements of equipment or systems in new buildings or major renovations to existing building
Savings	Measured load (kW) and hours of use data are used in defined equations to determine energy savings.	Measured load (kW) and hours of use from the post-installation period and estimated baseline kW and hours of use based on code are used in defined savings equations.

SUMMARY GUIDE: VERIFICATION BY EQUIPMENT OR END-USE METERING PROTOCOL

EXAMPLES OF END-USE METERING

The EUM Protocol includes seven examples of how the protocol is applied to different types of energy savings projects. Six of these examples are highlighted below.

Example 8.1
Scope: Motor upgrade in existing building
Approach: EUM - measured kW
Reference: EUM pg. 39

Example 9.1
Scope: New construction lighting improvements
Approach: EUM Absent baseline
Reference: EUM pg. 57

Example 8.2
Scope: New on/off controls for fans
Approach: EUM - measured kW, hours
Reference: EUM pg. 42

Example 9.2
Scope: Replacement of failed chiller
Approach: EUM Absent baseline
Reference: EUM pg. 58

Example 8.4
Scope: Constant flow to variable volume
Approach: EUM - measured kW, flow rate
Reference: EUM pg. 51

Example 9.3
Scope: New construction high efficiency motor
Approach: EUM Absent baseline
Reference: EUM pg. 60

BPA RESOURCES

BPA Measurement and Verification Resource Library

Equipment or End-Use Metering Protocol

M&V Protocol Selection Guide and Example M&V Plan

BONNEVILLE POWER ADMINISTRATION

SUMMARY GUIDE:

Meter-Based Energy Modeling Protocol

BONNEVILLE POWER ADMINISTRATION

OVERVIEW

Bonneville Power Administration's (BPA) *Verification by Meter-Based Energy Modeling Protocol* uses regression analysis of meter-based energy data and key independent variables to create mathematical models of the baseline energy consumption. Savings are then determined by subtracting the post-installation energy consumption from model adjusted baseline energy consumption. Savings for typical conditions can be determined if a post-installation period energy model is developed and adjusted to typical conditions and the baseline energy is also adjusted to typical conditions.

Meter-Based Energy Models:

- Require continuous energy and independent variable data
- Are developed using regression analysis, often using specialized software tools
- Are based on the empirical analysis of data
- Use of method requires sufficient accuracy of the baseline model
- Are best for existing buildings or systems whose operations are predictable and expected to remain consistent

WHEN TO USE

- Projects in existing systems and facilities with significant energy impacts (>3-5%)
- Energy and independent variable data are available for at least one year
- Building or system operations are consistent
- Energy interactions between measures are significant
- Expected savings are large compared to the uncertainty in the model
- Savings from measures are otherwise hard to quantify

WHEN NOT TO USE

- A code or standard practice baseline is required
- Post-installation monitoring period is limited
- Accuracy of baseline model is insufficient relative to savings
- Other changes occurred in baseline period or are expected post-installation
- Individual savings for one of several measures is needed
- Operations are inconsistent or expected to change

PROCEDURE

Collect Data

Step 1: Collect Baseline Data

- Energy use data for full range of operating conditions (e.g., 1 yr)
- Identify independent variables driving energy use (e.g., outdoor temperature) and collect data

Create Model

Step 2: Develop Baseline Energy Model

- Collect, clean, and graph data
- Select and develop a model
- Validate the model
  - Compare model statistics to expected level of savings

Post-Installation

Step 3: Adjust Baseline Model

Use post-installation conditions (e.g., outdoor temperatures) to adjust baseline energy

Step 4: Calculate Energy Savings

Measured energy from post-installation period is subtracted from adjusted baseline energy

REPORTING REQUIREMENTS

- Define the measurement boundary to encompass the building or system
- Document baseline system and impacts from measures
- Include energy and independent variable data
- Provide model development procedure and details on model:
  - Software used
  - Type(s) of models (e.g., change point, time of use and temperature)
  - Independent variables
  - Error or uncertainty in model

TIPS

- Use a common time interval (hourly, daily, weekly, or monthly) for all data
- Short-time interval data (e.g., daily, hourly) provides additional granularity
- Uncertainty in model should generally be no more than 50% at a confidence level of 68%
- Level of uncertainty in an energy model will vary with the data's' time interval
- Track and adjust for non-routine events (e.g., maintenance shutdown)

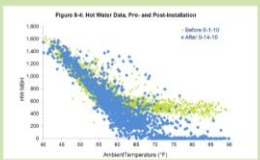
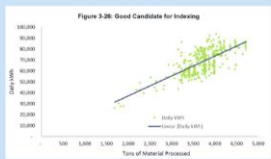
TOOLS & RESOURCES

Data analysis tools are available but require familiarity to use (i.e., a learning curve)

- **M&V Tools:** NMECR, ECAM, CalTRACK, UT
- **Statistical analysis:** R, SAS, Python
- **Weather Data:** NREL's TMY3 weather data, NOAA's historic weather data
- **Guidelines:** ASHRAE Guideline-14

APPLICATION SPECIFIC CONSIDERATIONS

Within the Meter-Based Energy Modeling Protocol there are two methods presented: energy modeling and modeling with energy indexing. Each method has some specific requirements and considerations summarized below.

	ENERGY MODEL	ENERGY INDEX
Overview	Develop a data-driven regression-based model(s) of the baseline energy use to an independent variable (e.g., weather). Savings are the difference between monitored energy use in the post-install period and the baseline energy use adjusted to monitored post-install conditions. Calculating normalized savings requires creating a post-installation energy model, and adjusting it and the baseline model to "normal" conditions. Savings are the difference between the two adjusted models.	Develop a data-driven regression-based model of the baseline energy use to an independent variable (e.g., production rate) and adjust it to "normal" conditions. Create a model of the post-installation energy use and adjusting it to "normal" conditions. Savings are the difference between the two adjusted models.
Use Cases	Use when the relationship between energy use and weather (and/or other independent variable) requires multiple regressions (e.g., change-point models) or the model is non-linear.	Use when the energy use is proportional to one or more independent variables (e.g., energy use per widget produced) where the regression model is linear.
Insights	Change point models can provide insights into system performance.	Method is not recommended with more than one independent variable.
Example Model		

EXAMPLES OF METER-BASED MODELS

The *Verification by Meter-Based Energy Modeling Protocol* includes three examples of how the protocol may be applied to different types of energy savings projects. The first example models measured heating and cooling energy, and the other two model the energy use of industrial equipment.

EXAMPLE 1
Replacement of leaking heating & cooling valves

Method:
Meter-Based Energy Models - End-use analysis

Reference: MBEM pg. 81

EXAMPLE 2
Modification to industrial pumping systems

Method:
Meter-Based Energy Models - Energy Use Indexing (kWh per kGal)

Reference: MBEM pg. 89

EXAMPLE 3
Replacement of compressed air equipment

Method
Meter-Based Energy Models - System level analysis

Reference:
MBEM pg. 93

BPA RESOURCES

Meter-Based Energy Modeling Protocol

Regression for M&V: Reference Guide

Commercial & Industrial SEM M&V Reference Guide

BONNEVILLE POWER ADMINISTRATION

SUMMARY GUIDE:

Estimating Peak Demand Impacts

BONNEVILLE POWER ADMINISTRATION

OVERVIEW

Bonneville Power Administration's (BPA) *Estimating Peak Demand Impacts Application Guide* discusses impacts from capacity savings on utilities, defines BPA's peak demand period, and provides several methods to estimate demand savings from energy savings projects.

Peak demand impacts:

- Affect generation, transmission, and distribution capacities
- Can impact cost effectiveness of projects for customers
- Are based on reductions during specific times of day/months which see maximum system loads
- May be determined using the BPA M&V Protocol selected for the project
  - Engineering Calculations with Verification
  - End-Use Metering
  - Meter-Based Energy Modeling
- Approach used to quantify depends on the data available
- Accuracy of demand savings estimates can vary and depend on data and assumptions used
- Are not used in BPA's incentive calculations
- Are not included in BPA's project reporting requirements

WHEN TO USE

- Utilities quantifying demand impacts from energy efficiency projects and programs
- Energy efficiency projects with substantial peak demand reductions that will:
  - impact utility planning, or
  - significantly change customer costs through peak kW charges or time of use rates

WHEN NOT TO USE

- Projects with no or low expected peak demand savings
- Projects with energy only (kWh) rates

PROCEDURES

1. Use direct estimation

- Requires hourly or sub-hourly data from baseline and post-installation period

- OR-

2. Use secondary resources

- Required when hourly data is not available
- Use with with inputs and outputs of energy savings calculations

End-Use Metering

- Use measured data from baseline and post-installation period
- Weather dependent measures should be adjusted to TMY3 weather using regression analysis

Meter-Based Energy Modeling

- Hourly models of the baseline and post-installation periods are adjusted to Typical Meteorological Year (TMY3) data
- Estimate saving during each hour in the peak period and average results
- Daily models should use load shapes to estimate the distribution of energy and savings across hours for efficiency only projects)

Engineering Calculations

- Hourly (8760) calculations can be used with coincident factor, if needed
- For bin hour analyses identify weather conditions during peak period

DEFINITIONS

Capacity or peak demand savings

- Difference in the average baseline and post-installation demand during the peak period time and/or weather conditions
- Uses the average reduction during the peak demand window

Load shapes show the average consumption or savings across a period of time (daily, weekly, yearly)

Coincident factor is the percentage of full power draw of the targeted equipment during peak period

Energy to demand factor for a specific measure or end-use is ratio of peak demand savings to energy savings

BPA Peak Period BPA defines the peak period as cold winter weekday mornings from 6:00 AM to 10:00 AM (hours ending 7, 8, 9, and 10 local prevailing time)

TOOLS & RESOURCES

Weather Data: NREL's TMY3 Weather Data
Load shapes: RTF, EPRI
Guidelines: *Uniform Methods Project Chapter 10: Peak Demand and Time-Differentiated Energy Savings Cross-Cutting Protocol*

Developed by Facility Energy Solutions

SUMMARY GUIDE:

Sampling for M&V: Reference Guide

BONNEVILLE POWER ADMINISTRATION

OVERVIEW

Bonneville Power Administration's (BPA) *Sampling for M&V: Reference Guide* can be used with retrofit isolation M&V protocols when the number of affected systems is too large to meter and analyze. Sampling allows use of a valid sample of the systems.

Sampling for M&V:

- Is used along with M&V protocols:
  - Equipment or End-Use Metering Protocol (EUM)
  - Engineering Calculations with Verification Protocol (ECwV)
- Details how to select valid samples
- Uses a sample of equipment measurements
- Requires groups of similar retrofits (e.g., lighting fixtures)
- Is used to reduce M&V expenses
- Reduces accuracy of reported energy savings
- Includes the use of limited statistics
- Emphasizes validating results of sampled measurements

WHEN TO USE

- Projects that include a 'population' of many similar retrofits
  - lighting upgrades, controls upgrades, rooftop unit replacements, motor replacements, industrial equipment
- Projects using either the EUM or ECwV M&V Protocol
- Sufficient samples to represent the entire population are required
- When additional uncertainty in savings estimates is not important

WHEN NOT TO USE

- Projects that include unique equipment
- Equipment with different operating conditions
- Where Meter-Based Energy Modeling M&V Protocol is used
- When project savings need to be very accurate
- Where metering is sufficient to cover all systems retrofit
- There is significant variability in the 'population' of retrofits

PROCEDURE

Collect Data

Step 1: Group data on planned retrofits

- Inventory all retrofits
- Grouped by their load and operating hours (pre and post)

Define Approach

Step 2: Select a sampling strategy

- Simple random samples
  - homogeneous population
- Stratified random samples
  - multiple groups within a population

Step 3: Assign level of variability

- 0 to 1 for each group

Step 4: Define desired accuracy

- Confidence and precision
- 90% confidence at ±10% precision is recommended

Step 5: Randomly select samples

- Include alternates

Use Samples

Step 6: Measure selected samples

- Include alternate samples

Step 7: Validate Results

- Overall precision of results

REPORTING REQUIREMENTS

- Define sampling procedure used
- Details on population and groups:
  - Population sizes
  - Characteristics of each group (e.g., load, performance, hours)
    - Assumed Cv for each group
    - Sample size selected and used
  - Confidence and precision targeted
  - Actual precision achieved
  - Calculation and adjustments made
- Other M&V details required by M&V protocol used

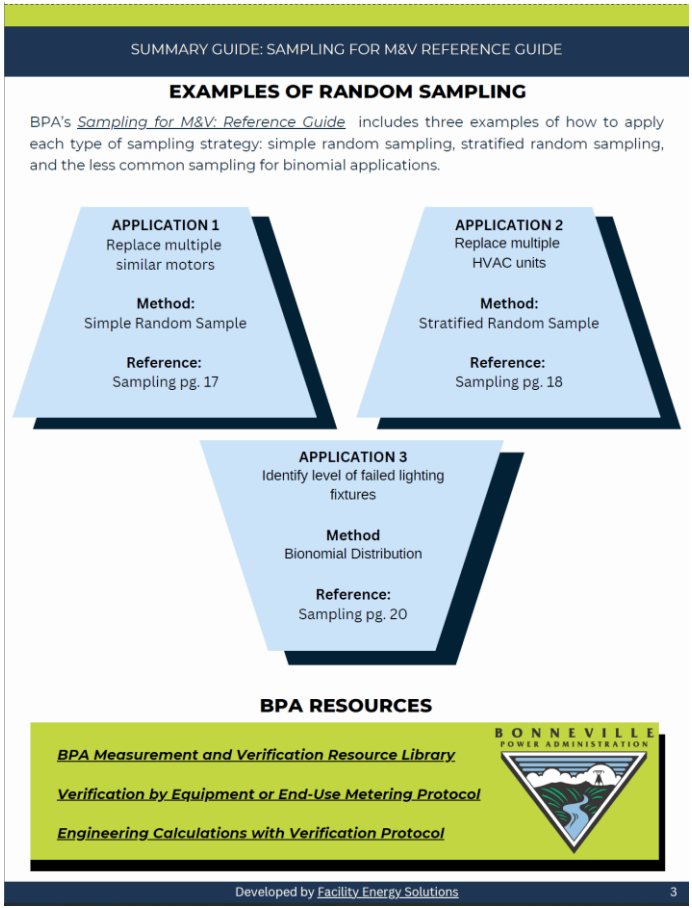
TIPS

- Use stratified sampling with multiple groups
- Group members of the population with identical characteristics together
  - Ensure groups are homogeneous
  - Exclude unique items and measure separately
  - Characteristics measured using samples must be uniform
- Characteristics include performance and usage metrics (e.g., power, operating hours)
- A large range of values results in a high Cv
- Assume a Cv or 0.5 for most groups
- Samples usually comprise <10% population
- Meter extra samples
- Define a method to field identify alternate samples

TOOLS

Generated random samples (0 to 1) in Excel:

- RAND()


SUMMARY GUIDE: SAMPLING FOR M&V REFERENCE GUIDE
EXAMPLES OF RANDOM SAMPLING
BPA's Sampling for M&V: Reference Guide includes three examples of how to apply each type of sampling strategy: simple random sampling, stratified random sampling, and the less common sampling for binomial applications.
APPLICATION 1
Replace multiple similar motors
Method:
Simple Random Sample
Reference:
Sampling pg. 17
APPLICATION 2
Replace multiple HVAC units
Method:
Stratified Random Sample
Reference:
Sampling pg. 18
APPLICATION 3
Identify level of failed lighting fixtures
Method
Bionomial Distribution
Reference:
Sampling pg. 20
BPA RESOURCES
BPA Measurement and Verification Resource Library
Verification by Equipment or End-Use Metering Protocol
Engineering Calculations with Verification Protocol
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POWER ADMINISTRATION
Developed by Facility Energy Solutions
3


SUMMARY GUIDE:
Sampling for M&V: Reference Guide
BONNEVILLE POWER ADMINISTRATION
SUMMARY GUIDE:
Estimating Peak Demand Impacts
SUMMARY GUIDE:
Equipment or End-Use Metering Protocol
SUMMARY GUIDE:
Meter-Based Energy Modeling Protocol
SUMMARY GUIDE:
Engineering Calculations with Verification Protocol
OVERVIEW
Bonneville Power Administration's (BPA) Engineering Calculations with Verification Protocol (ECwV) uses engineering algorithms to estimate baseline and post-installation energy use of equipment, systems, or buildings. Savings are the difference in estimated electricity consumption between the baseline and post-installation scenarios.
Engineering calculations:
Are either developed in spreadsheets (e.g., Excel) or in energy simulation modeling software (e.g., eQUEST)
Are based on the physics of systems
Do not require measured energy use
Require field verification and true up of calculations
Accuracy of savings estimates can vary and depend on data and assumptions used
Are intended for use on smaller projects
WHEN TO USE

Next Steps

Next Steps

- Review BPA's Version 3.0 and 3.1 M&V documents
  - BPA M&V Resources https://www.bpa.gov/energy-and-services/efficiency/measurement-and-verification
- Send any comments to:
  - Todd Amundson tmamundson@bpa.gov
- Additional M&V improvements are not identified at this time
  - Ideas are welcome!

Questions or Comments?

FACILITY energy solutions

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Thank you!

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