SUMMARY GUIDE:

Meter-Based Energy Modeling Protocol

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)

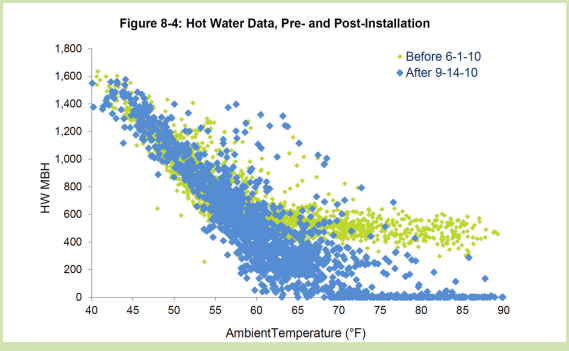
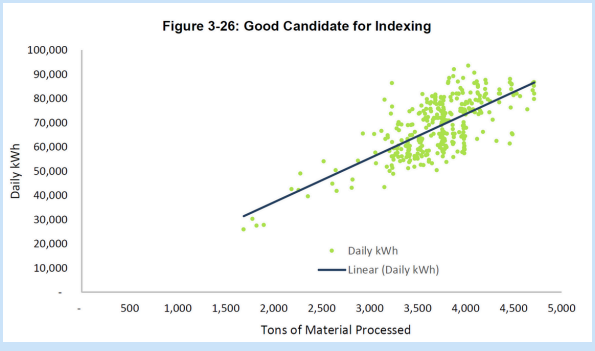
TOOLS & RESOURCES

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