California
Commissioning
Collaborative

Guidelines for Verifying Savings fro Commissioning Existing Buildings

Method 2: System or Equipment Energy Measurement

Mark Effinger, P.E.

September 13, 2012

Welcome!

Web-Meeting Notes:

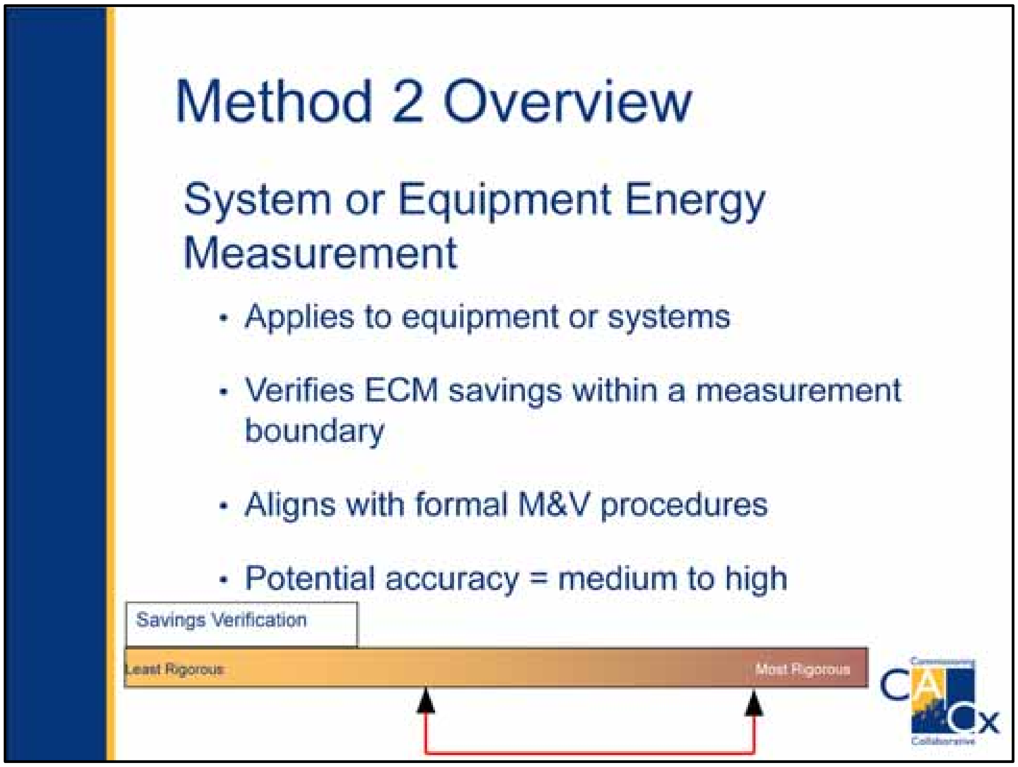
- All participant lines are muted
- Please submit questions via the Chat feature to Host
    - Find the Chat button at the top center of your screen (menu will expand down when hovered over)

Today's Speaker

Mark Effinger, PE, CMVP
PECI

Agenda

- Method 2 overview
- Process
- Characterizing Load and Hours of Use
- Calculations
- Proxies and Estimates

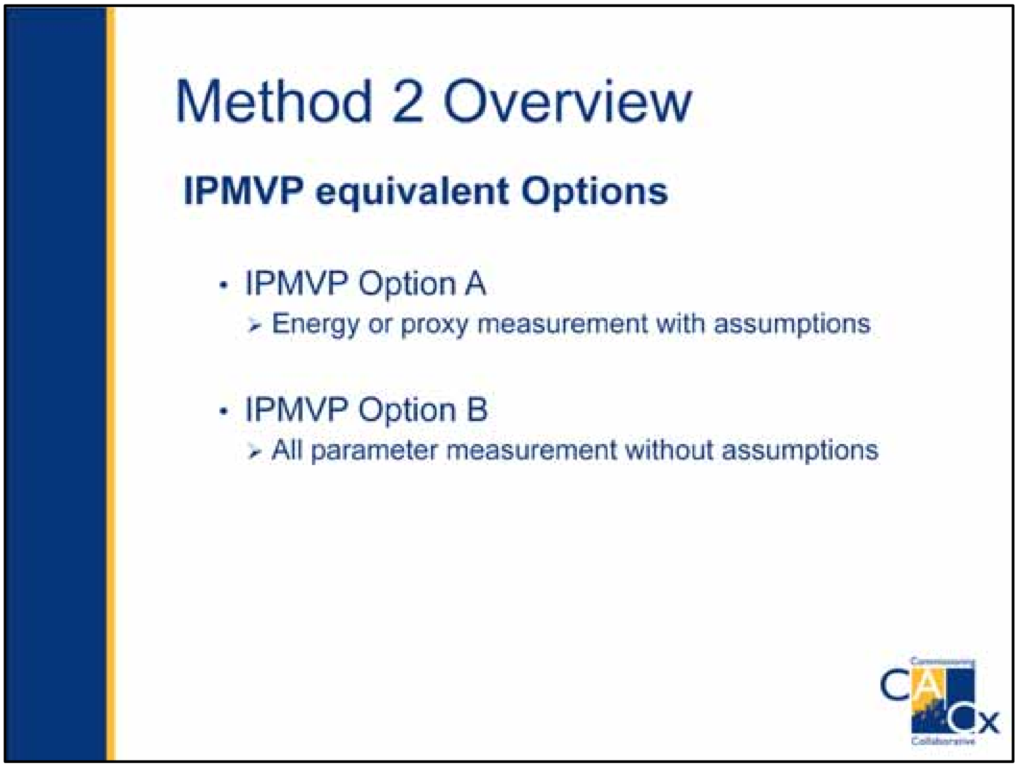


Method 2 represents an incremental step in rigor compared to engineering calculations discussed in last week's webinar. Similar to engineering calculations, the Method 2 approach quantifies savings from individual systems or smaller pieces of equipment.

Savings from individual ECMs can be quantified, but we need to pay careful attention to the measurement boundary. Multiple ECMs that have an impact within the measurement boundary (the same piece of equipment), cannot be resolved separately.

This chapter also goes into detail about separating energy use into the fundamental parameters of load and hours of use. We'll talk more about this later, but for now I'll mention that this activity aligns with formal M&V.

Method 2 requires direct energy measurements to quantify baselines and post-installation conditions, which is a key differentiator from Method 1. Remember that Method 1 uses simple performance data and engineering assumptions to calculate energy use. By measuring energy use directly, Method 2 cuts out many of the assumptions and engineering judgment which should improve overall accuracy. Energy measurements = potential for more cost.

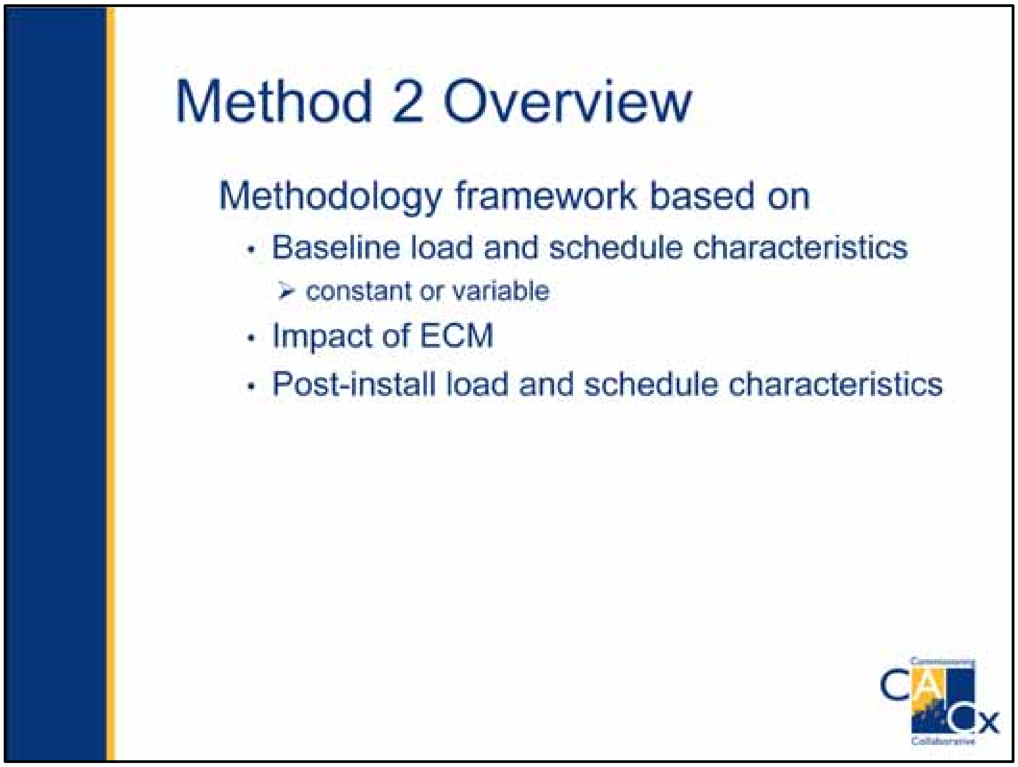


Method 2 is essentially a retrofit isolation approach, which should look somewhat similar to IPMVP Options A and B. While the methodology was originally designed for retrofit applications, it will still work for EBCx type projects.

In summary, Option A is typically defined by a Key Parameter measurement, where the least known parameter, or the parameter most impacted by the ECM is measured, and the other is estimated. For example, if an ECM impacts only operating hours and not load, then Option A would require measurements of operating hours both before and after the ECM installation, but the load parameter could be estimated. Under a Method 2 approach, we'd always recommend a measurement of the load parameter in at least one measurement period. The estimation of energy parameters is discussed in this guide.

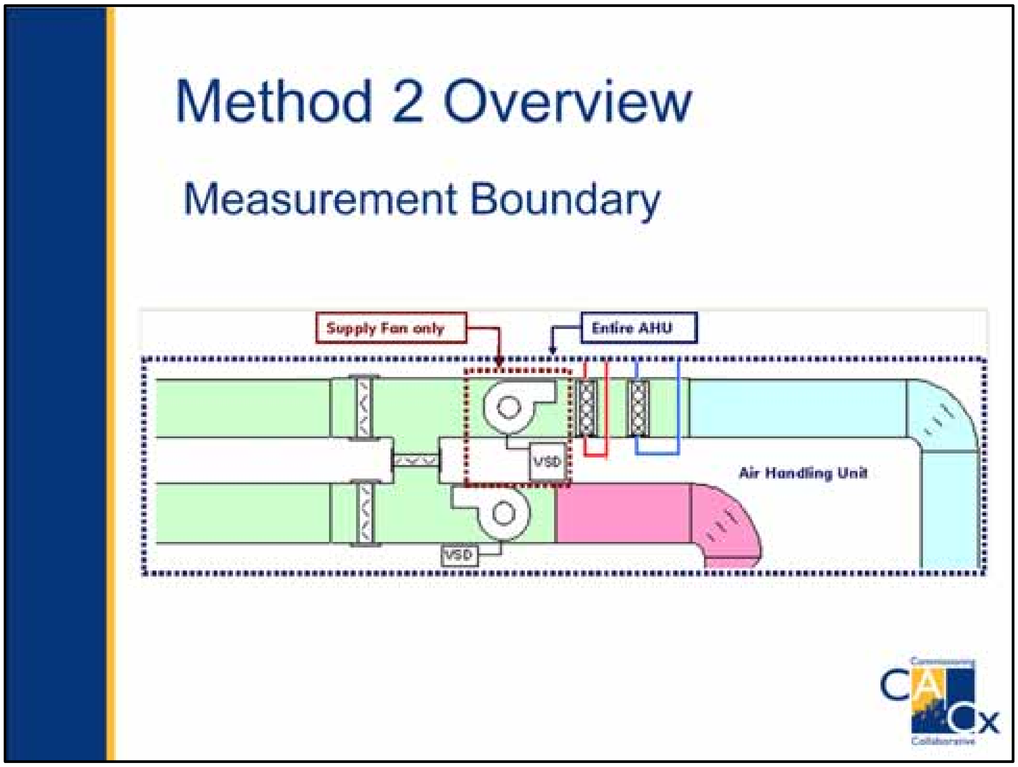
Option B requires measurement of all energy parameters, (both load and hours of use). Which aligns well with Method 2.

Also, for those of you who have read or are familiar with the content of ASHRAE Guideline 14, you will notice similar themes scattered throughout the Method 2 approach.



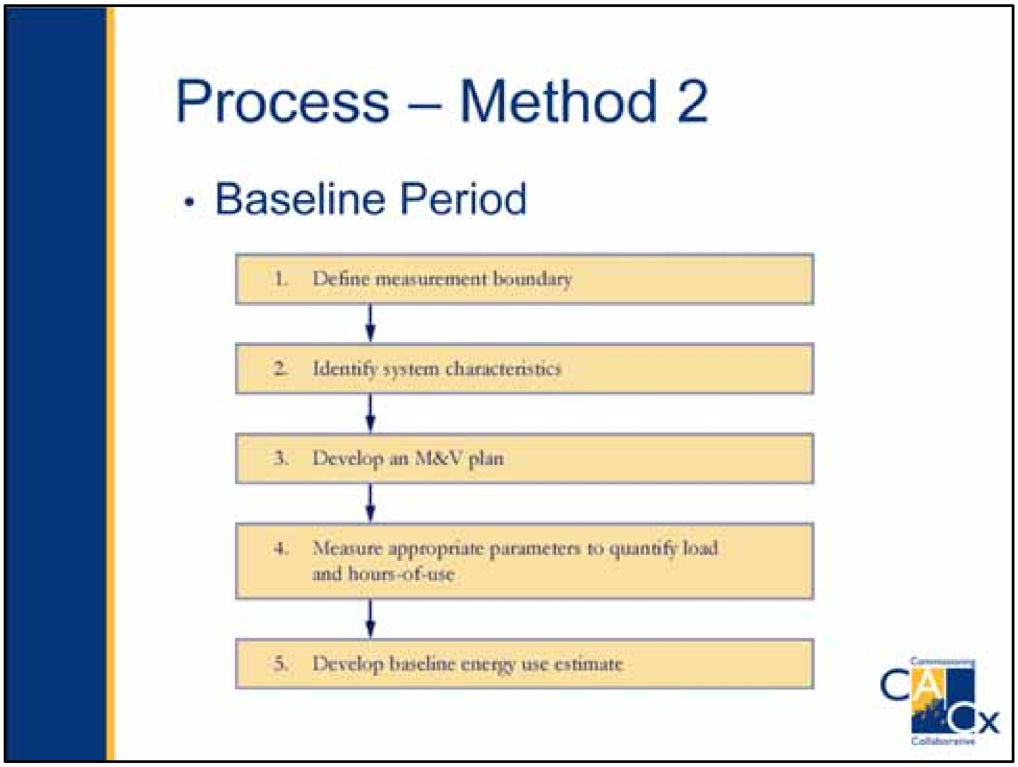
We've already mentioned that Method 2 involves separating energy use into load and hours of use. This guide also goes into detail about classifying these individual parameters as either constant or variable and understanding how the ECM implementation will change this classification. Why is this classification exercise recommended?

The level of measurement required to quantify each energy parameter depends on whether the parameter is classified as constant or variable, and also on how the ECM installation impacts these characteristics. Constant parameters may only require a simple spot measurement while variable parameters typically require substantially more data



This method applies to equipment systems with loads that can be isolated and measured, or correlated to other measured parameters through confirmed engineering or statistical relationships

If multiple ECMs affect the same equipment, only the cumulative energy effect can be verified. Savings from multiple individual ECMs cannot be resolved. This method will not account for the potential interactive effects between ECMs installed across multiple systems. EBCx measures that affect multiple pieces of equipment that are not part of a single system are not ideal applications for this method.



The process for Method 2 is laid out step-by-step in the guide. Shown here is the process that occurs during the baseline period.

First, we define an appropriate measurement boundary around a piece of equipment or system affected by a recommended ECM. This step begins after ECMs are identified by the investigation phase of a typical EBCx process.

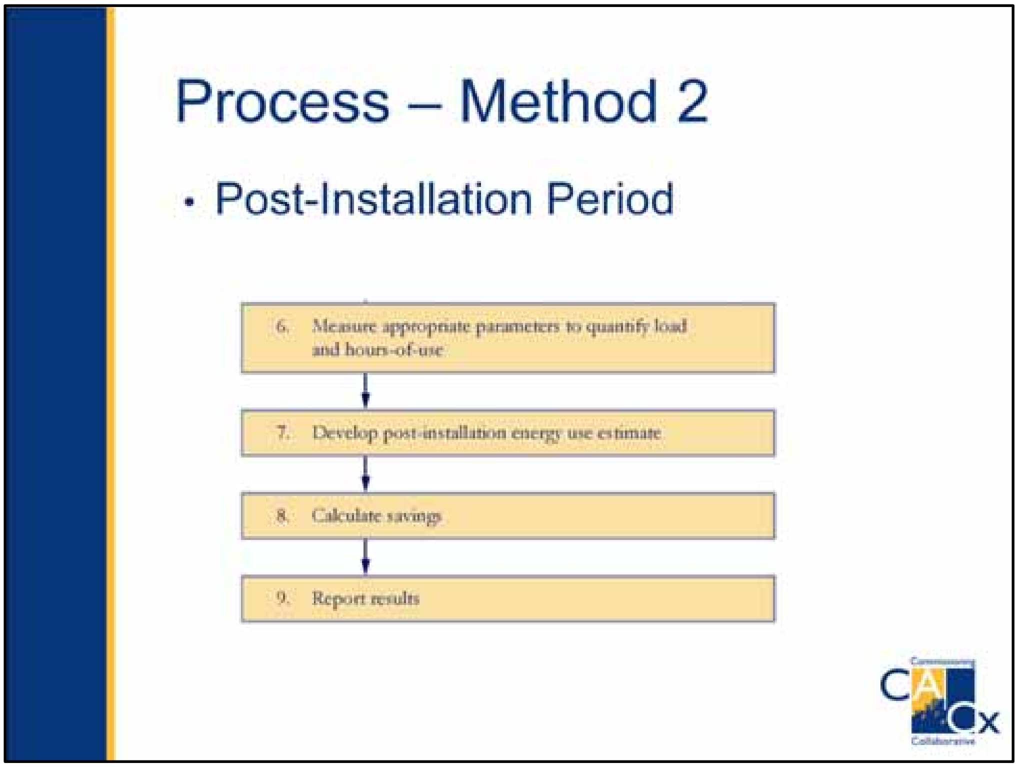
Next, the baseline and post-ECM characteristics of load and hours of use should be evaluated and classified as variable or constant. Any impacts the ECM has on these parameters should also be identified. This exercise will identify how much data and effort is required to quantify each parameter.

Once we know what is required to quantify the energy parameters, this information should go into an M&V plan.

Measurements of the energy parameters, or their proxies, and other required non-energy parameters including driving variables such as outdoor air temperature and occupancy are collected for the monitoring duration defined in the M&V plan. Proxies, if applicable, are confirmed as appropriate representations of energy use.

An appropriate calculation technique is selected and applied to combine load and hours-of-use parameters into an estimated baseline energy use estimate. The techniques applicable to a

Method 2 approach are typically:
- Simple calculations
- Spreadsheet calculations

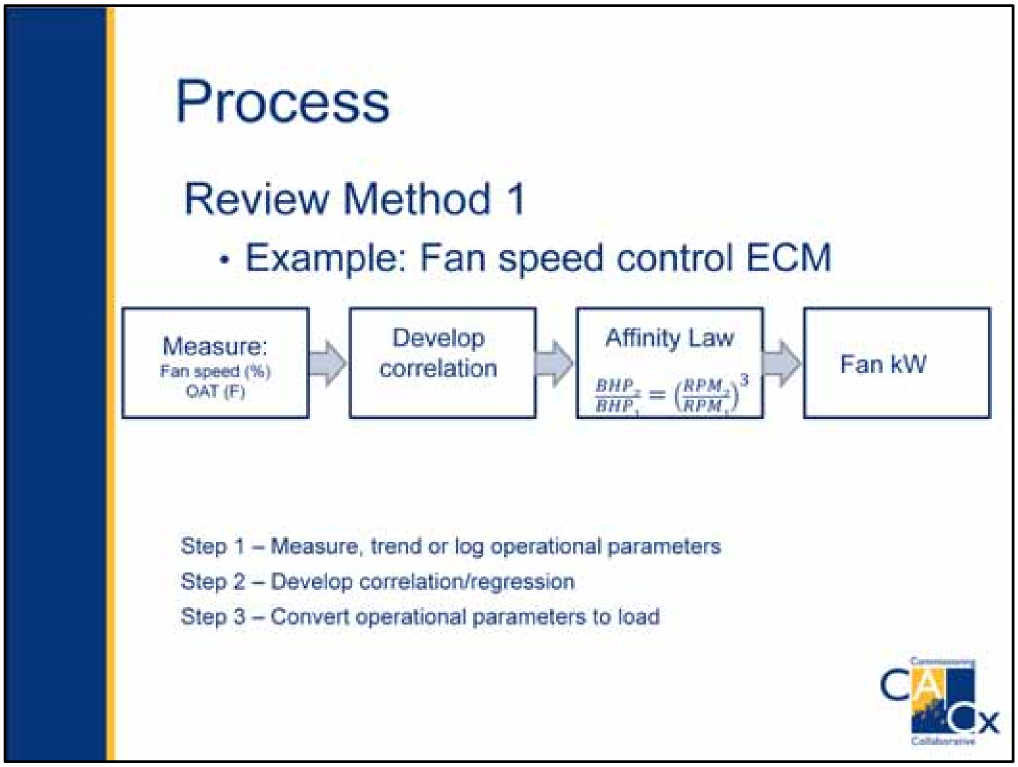


The Method 2 procedures assume that the ECMs are installed through the normal EBCx process and that the operational component of the measures have been confirmed. Chapter 2 of this guide (also discussed during the first webinar), includes a discussion on the difference between operational verification and M&V.

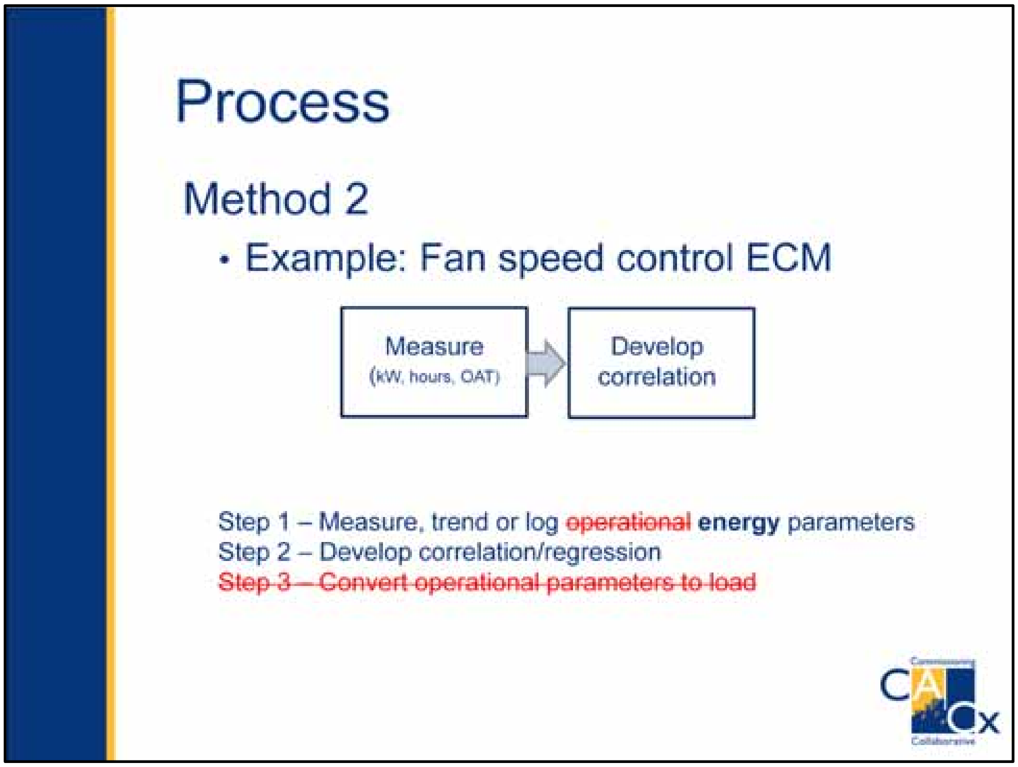
After the ECMs are installed, Method 2 again requires the collection of data that quantifies the loads and hours of use. Again, these parameters are converted into post-installation energy use using either simple or spreadsheet calculations.

The baseline and post-implementation energy use estimates are normalized by adjusting the baseline and post-install equations to the same set of conditions (often outside air temperature from TMY data). The difference between baseline and post-implementation energy use estimates is the verified energy savings.

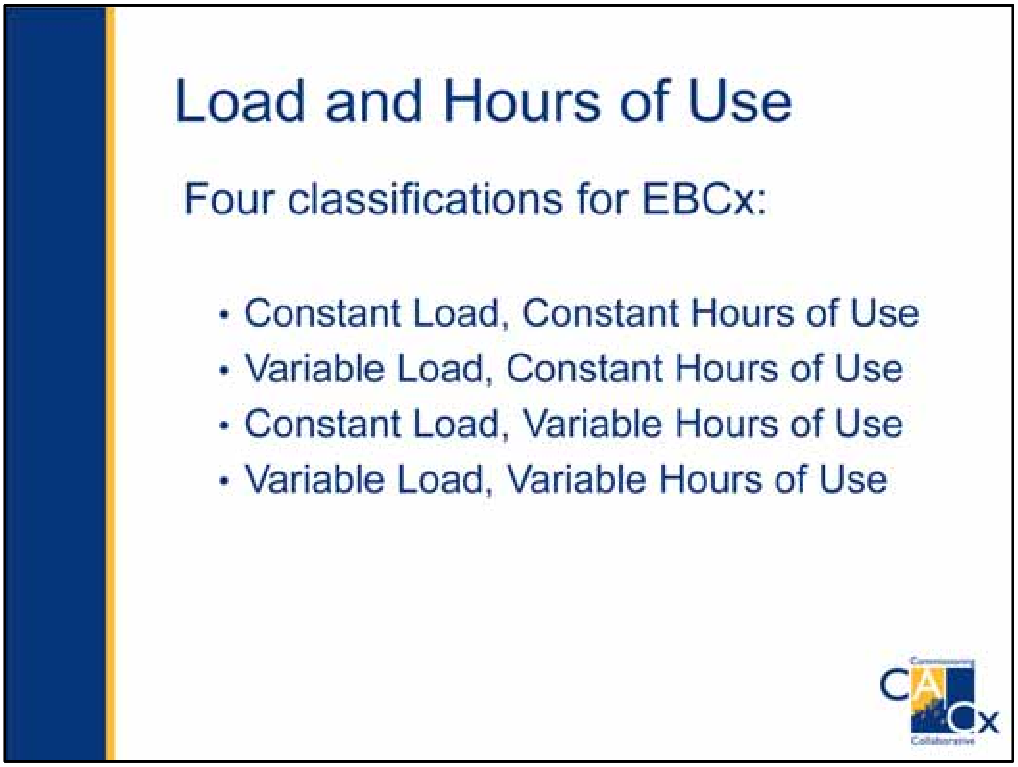
Notice that the verified savings are not available until after post-installation data is collected.



To help draw a distinction with Method 1, let's look at a simple example of a data collection and analysis process for an ECM that improves fan speed control. Since this measure involves a variable load, it's likely that a spreadsheet calculation would be required. uses measured operational data and fundamental engineering equations, such as the fan affinity laws, to estimate energy use. When converting between operational parameters and load, there are inherent assumptions that are made.

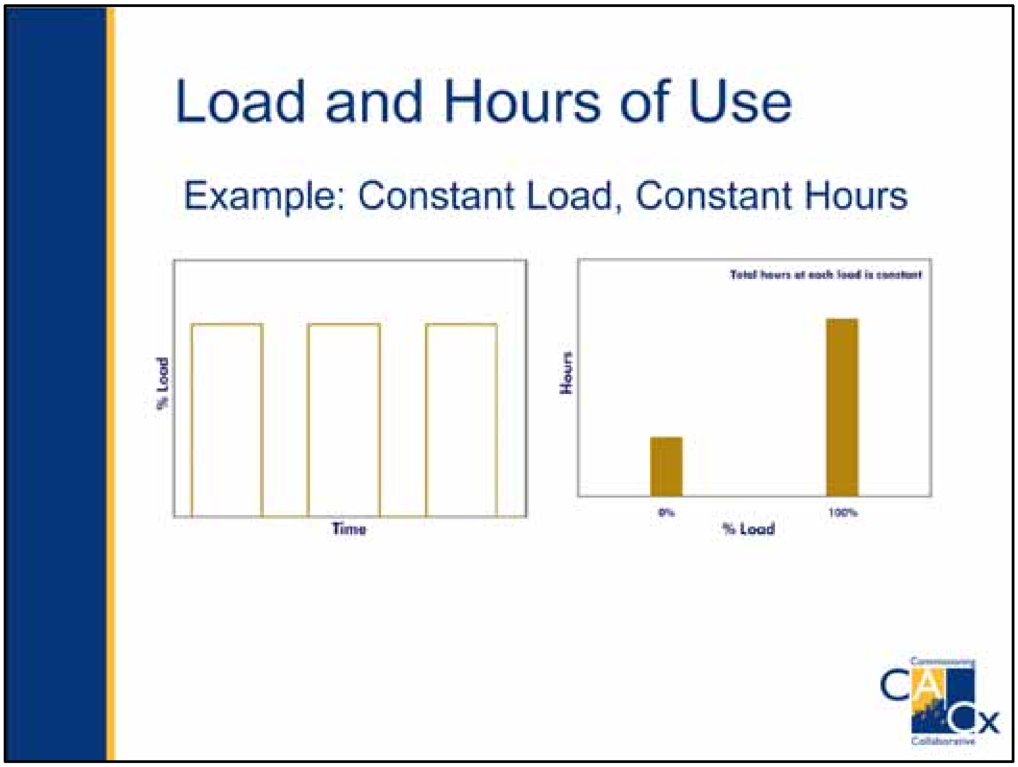


Method 2 focuses directly on the energy parameters, so the use of engineering assumptions and judgment should be minimized. Removing the intermediate steps to get to an energy correlation should improve the overall accuracy, or at least improve the confidence in the final savings estimate when compared to a Method 1 approach.



As we already mentioned, understanding the basic characteristics of the system operation both during the baseline period and after the installation of the ECM allows for proper development of the M&V plan.

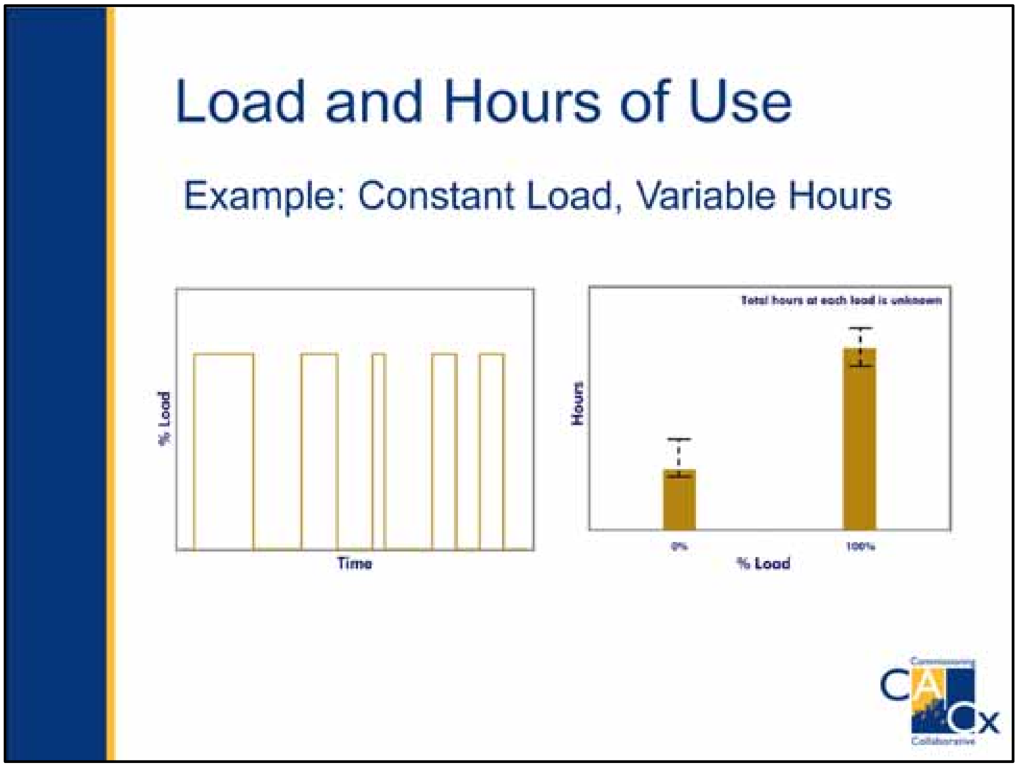
Knowing how much variation a parameter experiences dictates how much data is required to quantify that parameter. Constant values can be quantified fairly quickly and require very little monitoring. A spot measurement of load, or perhaps monitoring hours of use over a single week may be adequate to account for all operating conditions. Variable loads or use will require more monitoring time to fully quantify the parameters. How much time…depends on how much variation. You'd typically want to capture as much of the operating conditions as possible during the monitoring periods.



The simplest classification is constant load/constant hours of use. Simple calculations are typically all that are required to develop estimates of energy use for this classification.

Examples of equipment with constant load, constant hours of use operating characteristics include:

- Lighting under time clock control
- Constant volume air handling units under time clock control
- Water fountain pumps



When either of the energy parameters experiences variation, additional data collection is required. In this example of constant load, variable hours, a spot measurement might be sufficient to quantify the load, but hours-of-use will require a little more effort to quantify. The shorter the monitoring period is for variable parameters, the greater the risk that you aren't capturing a complete picture.

Examples of equipment with constant load, variable hours of use operating characteristics include:

- Lighting under occupancy sensor control
- Constant speed cooling tower fan operation (schedule varies with outdoor air conditions)
- Hot water or chilled water constant volume pumping (schedule varies with boiler/chiller operation)

Basic Equations

- Fundamental Energy Saving Formula

$$kWh_{saved} = \sum(kW_{base} * Hours_{base}) - \sum(kW_{post} * Hours_{post})$$

This equation demonstrates the general process for combining the energy parameters from the baseline and post periods to produce your energy savings estimate. This general equation will apply to all classifications of variable or constant energy parameters that we already discussed. A key take-away here is the classification of parameters does more than provide insight into monitoring lengths…it also helps to simplify the use of this equation.

Basic Equations

Constant Load, Constant hours of Use

ECM Impact	Electrical Energy Savings
Changes load only	$kWh_{saved} = (kW_{base} - kW_{post}) * Hours_{base\_or\_post}$
Changes hours-of-use only	$kWh_{saved} = kW_{base} * (Hours_{pre} - Hours_{post})$
Changes load and hours-of-use*	$kWh_{saved} = (kW_{base} * Hours_{base}) - (kW_{post} * Hours_{post})$
Changes load from constant to variable*	$kWh_{saved} = (kW_{base} * Hours_{base}) - \sum (kW_{post} * Hours_{post})$
Changes hours of use from constant to variable*	$kWh_{saved} = (kW_{base} * Hours_{base}) - (kW_{base} * \sum (Hours_{post}))$
Changes both load and hours of use from constant to variable*	$kWh_{saved} = (kW_{base} * Hours_{base}) - \sum (kW_{post} * Hours_{post})$

CACx Commissioning Collaborative

This slide demonstrates the possible iterations of the fundamental energy savings calculation for a constant load, constant hours end-use. Let's take a look at the first line this table…if an ECM reduces one constant load to another constant load, we can get to the energy savings estimate using a single spot measurement in the baseline and another in the post.

While these equations are fairly academic in nature, they demonstrate the fundamental process that's embedded in our typical engineering calculations. The common calculations approaches described in last weeks webinar are also used in a Method 2 approach. For those of you that missed last week's webinar, let's look at a brief example of the calculation approaches.

Calculation Example

- Simple Calc:
  - Applicable for constant applications

	A	B	C	D	E	F
1	Baseline Hours	Fan Load (kW)	Baseline Energy Use (kWh)	Proposed Hours	Proposed Energy Use (kWh)	ECM Energy Savings (kWh)
2	8,760	12.1	106,259	4,680	56,768	**49,490**

Here we have an example of a simple calculation for an ECM that reduces the operating hours of a constant load.

Calculation Example

- Spreadsheet Calcs:
  - Applicable for variable applications

Regression:

kW= 0.543*OAT + 20.345 from trends

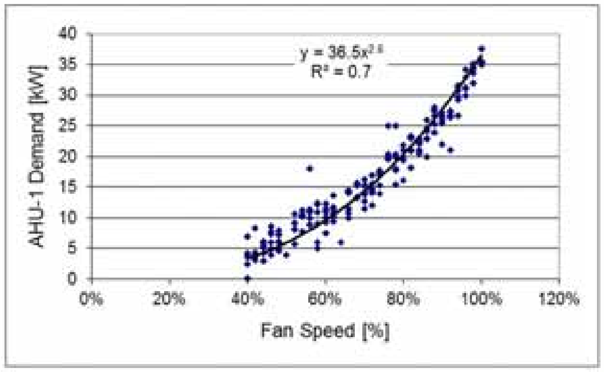
Calculations

Dry-bulb outside air temperature, °F	Occupied operation bin hours (M-F 6a-10p, Sa 7a-5p)	Baseline load (kW)	Baseline Energy (kWh)	Proposed operation bin hours	Proposed energy use (kWh)	Energy savings, (kWh)
89	1	69	69	1	69	0.0
87	4	68	270	4	270	0.0
85	11	67	732	11	732	0.0
83	10	65	654	10	654	0.0
81	34	64	2,187	34	2,187	0.0
79	45	63	2,846	45	2,846	0.0
77	38	62	2,362	38	2,362	0.0
75	157	61	9,588	157	9,588	0.0
73	322	60	19,315	322	19,315	0.0
71	382	59	22,499	382	22,499	0.0
69	430	58	24,859	430	24,859	0.0
67	526	57	29,838	526	29,838	0.0
65	470	56	26,151	470	26,151	0.0
63	516	55	28,150	0	0	28,150
61	450	53	24,061	0	0	24,061
59	219	52	11,472	0	0	11,472
57	347	51	17,800	0	0	17,800
55	389	50	19,532	0	0	19,532
53	151	49	7,418	0	0	7,418
	4502			2,430		108,431 kWh

The second and more complex example shown here is typical spreadsheet calculation using a bin approach. In this example, the ECM is an outside air lockout that eliminates hours of operation at temperatures below 65F. Notice that a regression was developed directly between load and temperature.

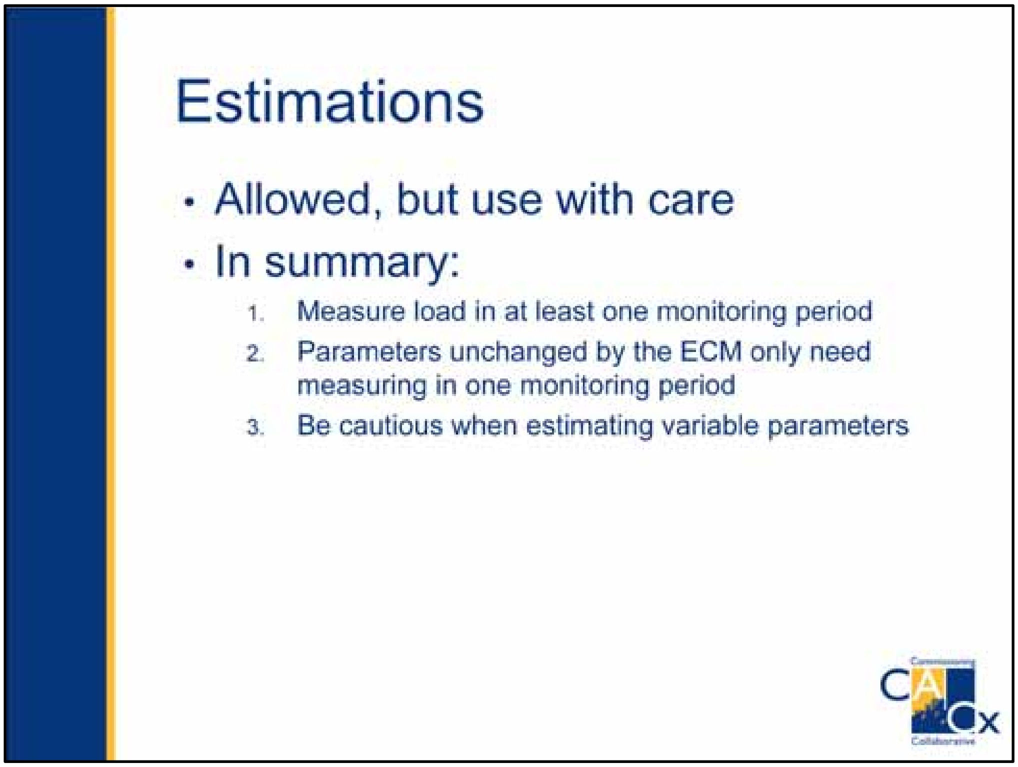
Proxies

Confirming a relationship between speed and kW



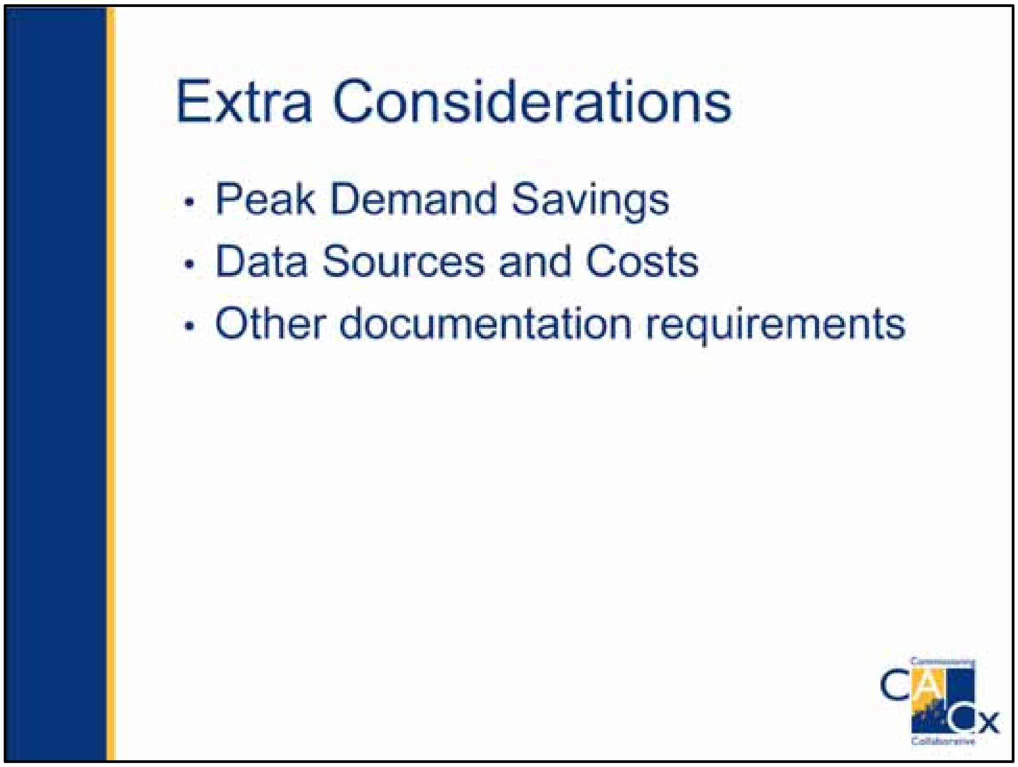
So far, we've focused solely on the use of directly measured energy parameters, but Method 2 can apply to operational parameters. However, a Method 2 approach requires that any operational parameter is proven to represent the energy parameter.

In this graph, you see a regression between fan speed and the kW demand for the fan motor. Using this data, we can prove the relationship between fan speed and power, so fan speed could act as a proxy for load.



IPMVP allows for estimation of non-key parameters when using Option A. Therefore, an ECM that affects only hours of use, and not load, Option A would require measurement of the hours of operation in the baseline and post-installation periods, but load could be estimated in both.

Method 2 puts more emphasis on measurement of energy, and for this example, would require the measurement of load in at least one of the monitoring periods.



Since the calculation approaches for method 2 are similar to method 1, the same limitations in determining peak demand savings are present. Method 2 can only produce an estimate of demand savings using the more complex spreadsheet calcs (which include either bin-based, or 8760 calculations). For most projects, it's not likely the baseline and post-installation monitoring periods would occur during peak demand periods, so the demand impacts will likely be extrapolated and should be considered approximations only.

The Method 2 data requirements may fall outside the normal realm of EBCx data collection. BAS points or existing power meters on the equipment impacted by the ECMs are not as common as other sensors that record operational parameters such as temperatures and pressure. If additional metering is required, costs of utilizing this method can quickly increase.

It's also important to note that Method 2 focuses on savings verification. If there are other documentation requirements from the project, such as operational verification, these efforts are in addition to the core Method 2 procedures. Make sure you are aware of and follow and additional documentation requirements.

Q&A

- Please submit questions via the Q&A box
  - Look for menu at the top center of your screen (it will expand down when you move your mouse over it) and select Chat box
  - Send questions to "Host"

2012 Meeting Dates

Date	Format
October 18, 2012	Webinar
December 6, 2012	In-person, host TBD

Verification of Savings Guidelines Webinar Series

Topic	Speaker	Date	Time
Guidelines Overview and Selecting a Method	David Jump, QuEST	Aug. 30	12:00-1:00 Pacific
Method 1: Engineering Calculations with Field Verification	Lia Webster, PECI	Sept.6	12:00-1:00 Pacific
Method 2: System or Equipment Energy Measurement	Mark Effinger, PECI	Sept. 13	12:00-1:00 Pacific
Method 3: Energy Models Using Interval Data	David Jump, QuEST	Sept. 20	12:00-1:00 Pacific

Thank you for participating!

www.cacx.org

Let us know what you thought of the meeting.

Please respond to the post-meeting survey. A link will be emailed to you.