California Commissioning Collaborative

Guidelines for Verifying Savings fro Commissioning Existing Buildings

Method 1: Engineering Calculations with Field Verification

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September 7, 2012

Welcome!

Web-Meeting Notes:

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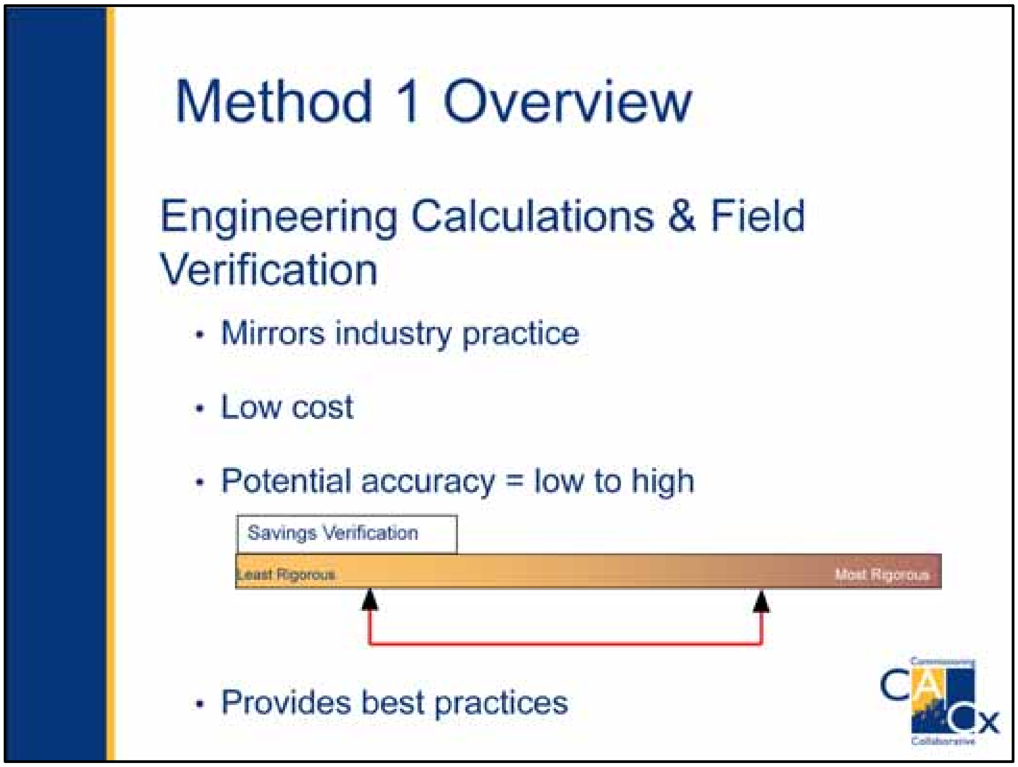
Agenda

- Method 1 overview
- Process
- Calculation examples
- Field verification
- Calculation best practices
- Resources

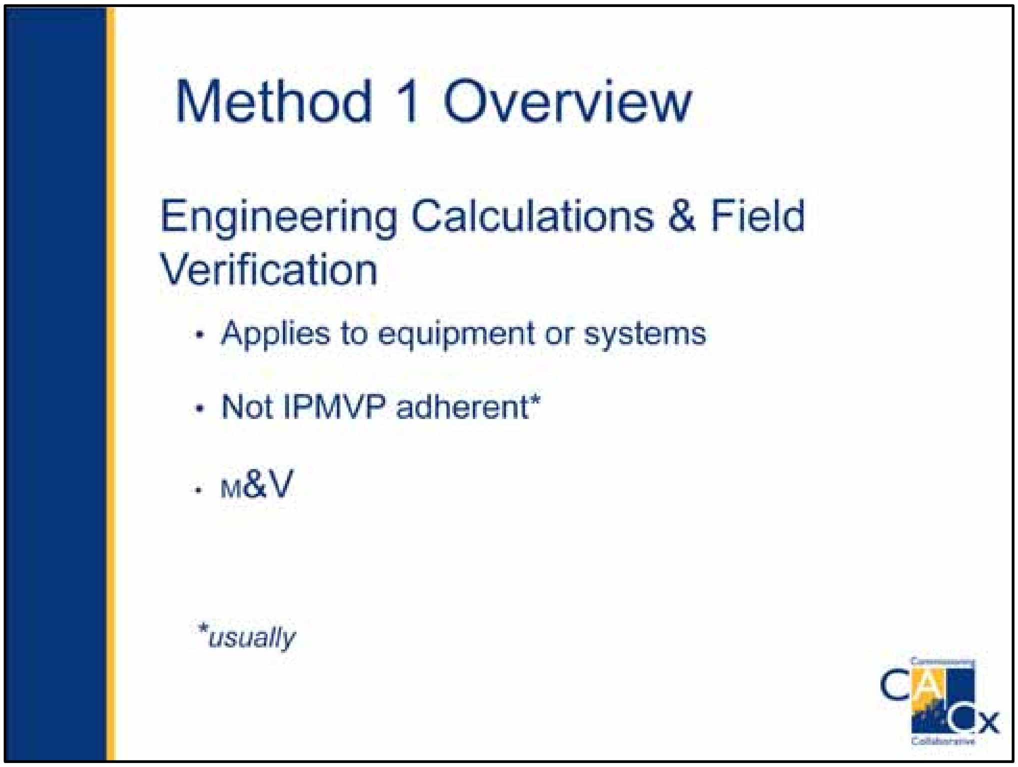


Method 1 is widely used in the energy efficiency industry, both in private and utility based projects. Though this is a far reaching approach, there has been very little guidance available. This lack of guidance and widespread use are the main reasons Method 1 was included in these guidelines.

Custom calculations provide a low cost means to estimate individual measure level energy savings using data collected from spot measurements or longer term performance trends, and from other building and equipment documentation.

Accuracy of the resulting savings estimates can vary widely based on the quality of the engineering assumptions used, so strong technical expertise is required. The ability to use various types and durations of field data makes this a flexible approach that can be tailored toward the available budget.

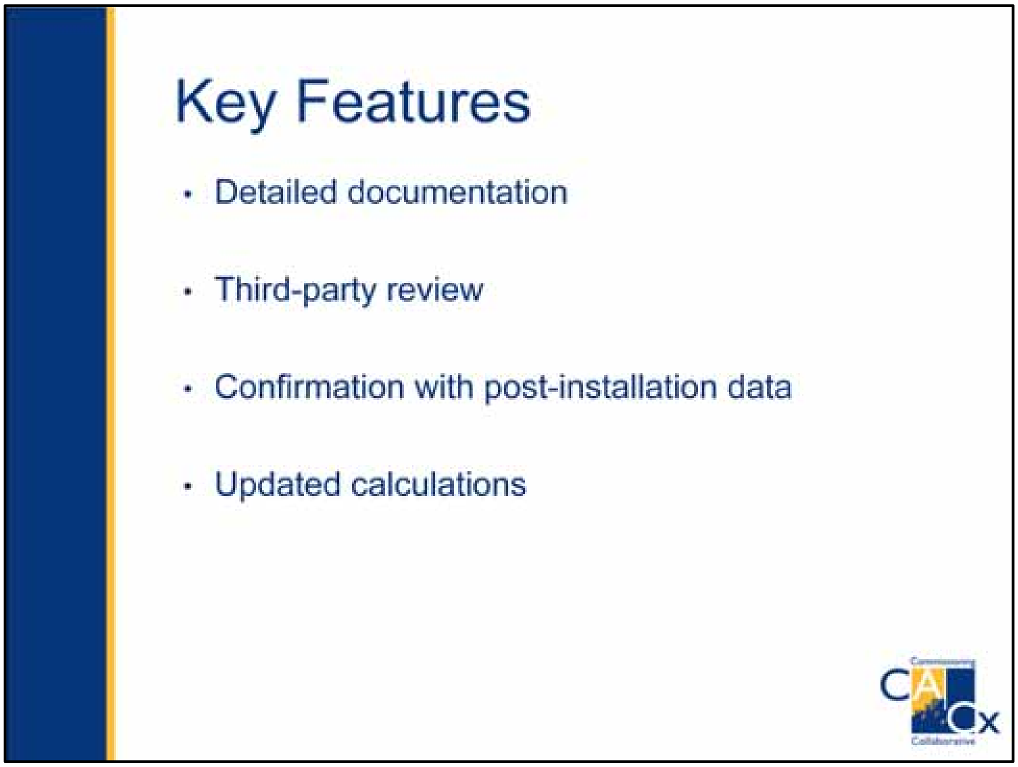
Due to the potential variation in accuracy, this Method includes several best practices to improve the quality of the engineering estimates.



Engineering calculations can be used to evaluate the energy performance of systems or individual pieces of equipment such as lighting, chillers, boilers, cooling towers, fans, pumps, air handlers, etc. These calculations may include simple calculations, spreadsheet based methods, or uncalibrated simulations.

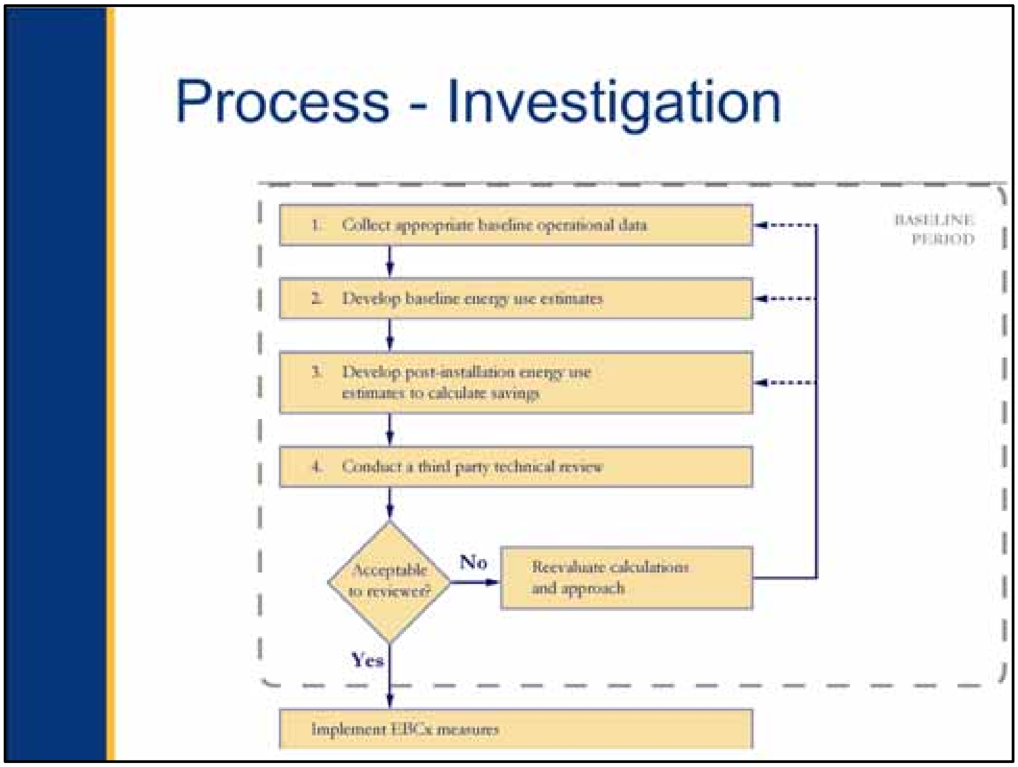
Specific measurements are not required, but measured operational data from the EBCx process is utilized to calculate energy use. Other data that may be utilized in the calculations include weather data, system design information, and manufacturer's specifications. Energy measurements are not typically utilized, as that would be Method 2 of this guideline.

In IPMVP, verification includes both energy measurements and operational verification. This method includes only operational verification. In some cases, however, this method can be adherent to IPMVP Option A.



One of the key elements of Method 1 is providing transparency in the energy calculations by including detailed documentation of main assumptions and sources of the data used. Other requirements include:

- A third-party review to ensure the recommended ECMs, calculation approaches and savings claims are reasonable for the situation at the specific project.
- Enhanced assurance that final savings estimates are accurate by incorporating post-installation data to confirm assumptions.
- Updated calculations, if necessary, based on the post-installation data to reflect actual post operational conditions.

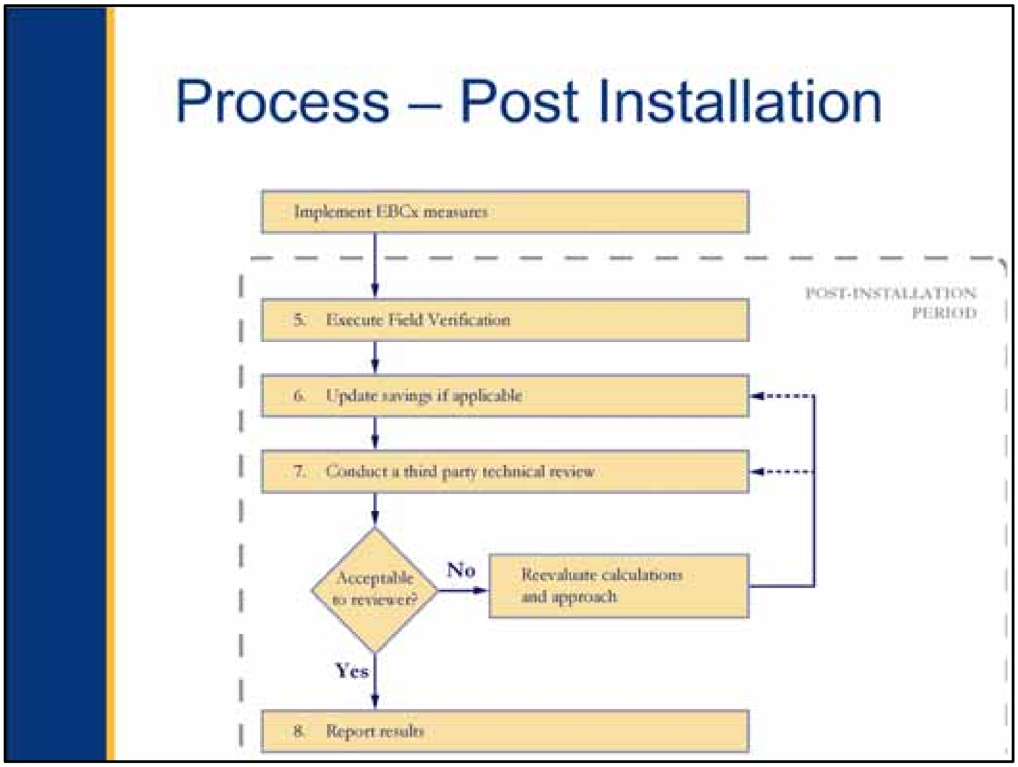


The process for Method 1 is laid out step-by-step. The first element is the collection of baseline data. This data is a key element, and should be sufficient to use as a basis for calculating energy use, and must also show the performance deficiency that is the basis for the recommended ECM. (Data collection strategies are provided for key EBCx measures.)

Next, baseline energy use is estimated with engineering calculations. Calculation approaches include simple calculations, spreadsheet based methods, or uncalibrated simulations. (Some direction on when to use the various methods is provided.) All assumptions must be justified and documented, and intermediate calculation steps should be shown wherever possible so the calculation is easy to follow by a third-party reviewer.

The estimation of the energy use after the ECM is developed based on the expected impact of the ECM. This estimate should be developed in a way that allows for future true-ups based on actual performance of key parameters.

Finally, a third party expert reviews the calculations for overall appropriateness. Once validated, these estimates may be used to move forward with implementation.



After implementation of them measures, field verification is executed to demonstrate the performance is aligned with the expectations of the ECM. In general, the post-installation data should be the same as (or similar to) the baseline data.

(Data collection strategies for verification are provided for key EBCx measures and will be discussed later in this presentations.)

If the operational data collected shows the operation differs from the original expectations, the energy use estimates should be updated.

A final peer review is then conducted before reporting results.

Calculation Example

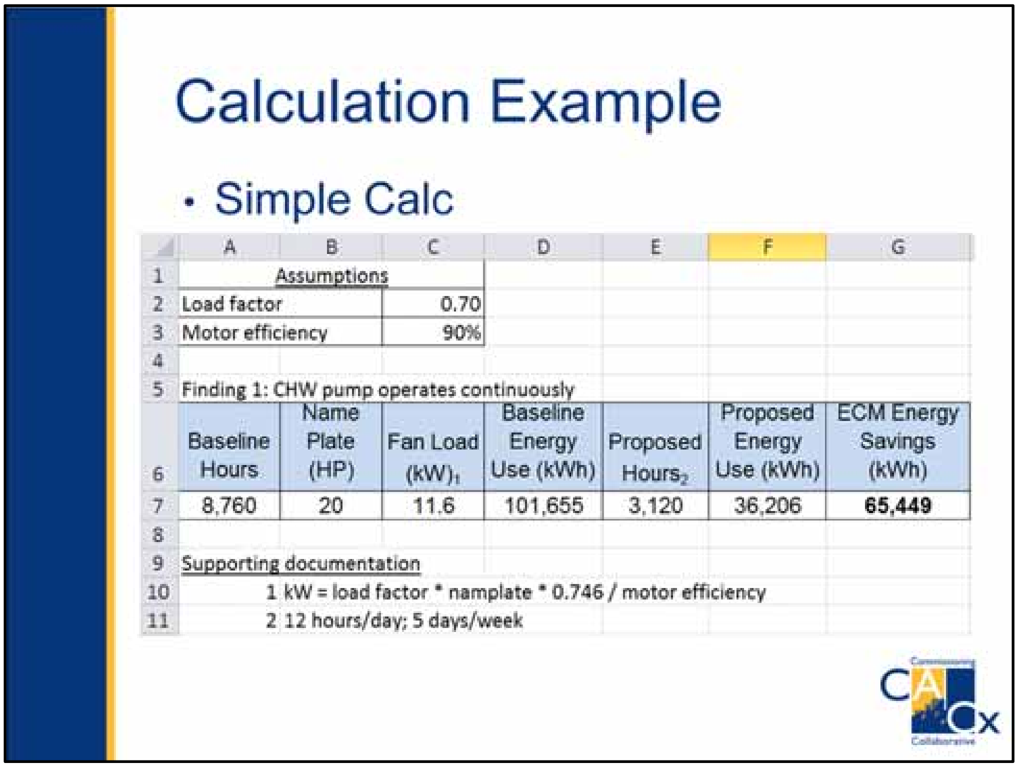
Purpose	Equation
Energy content of air	$Q = 1.08 \times CFM \times \Delta T$
Energy content of water	$Q=500 \times GPM \times \Delta T$
Pump energy use	$BHP = (GPM \times \Delta P_{(psi)})/(1714 \times \eta_{pump})$
Fan energy use	$BHP = (CFM \times \Delta P_{(in\ wg)})/(6356 \times \eta_{fan})$
Fan affinity laws*	$(BHP_2/BHP_1)=(CFM_2/CFM_1)^3$

Although uncalibrated simulations can be used, most EBCx savings estimates are based on spreadsheet calculations. Executing energy calculations from operational data and engineering assumptions requires experience and expertise, and influences what field data is required. Method 1 provides guidance in these areas.

One strategy that is helpful in executing accurate energy use calcs is quantifying loads and hours of use parameters separately. Determining what variables will be measured (or estimated) to determine loads and operating hours is a key step.

Some of the basic engineering equations that are often used to determine load from operational parameters are shown above. These equations are used along with equipment specifications, measured operating parameters (status, speed, temperature, flow, pressures) and driving variables (outdoor temperatures, occupancy) to determine the load or a load profile.

Measured data is the preferred approach for determining operating hours, since extrapolating from a building's "Schedule" will often result in incorrect estimates.

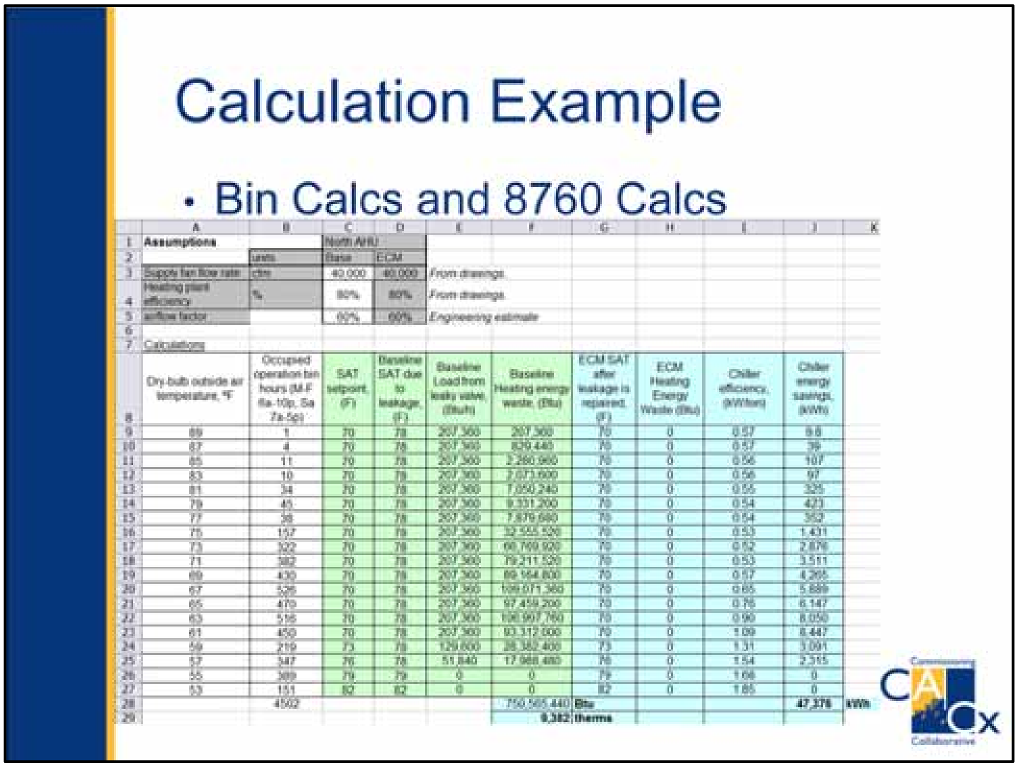


Baseline Hours	Name Plate (HP)	Fan Load (kW)[1]	Baseline Energy Use (kWh)	Proposed Hours[2]	Proposed Energy Use (kWh)	ECM Energy Savings (kWh)
8,760	20	11.6	101,655	3,120	36,206	**65,449**

Sometimes, elaborate or complicated calculations are not needed to present a reasonable estimate of energy savings.

When developing any form of calculation, provide clear documentation of any assumptions used. Consider augmenting these assumptions with data collected form the site. Show and photographs, screenshots, spot measurements or even trend data that support the claims made in the calculations.

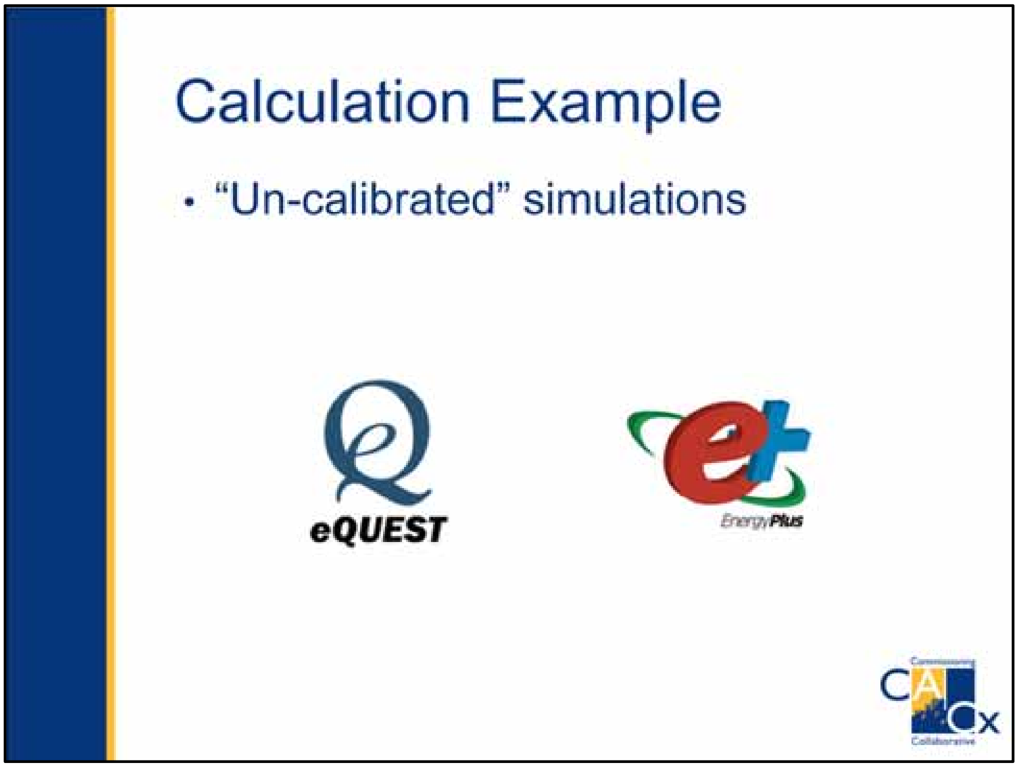
In this example, basic engineering equations and assumptions on motor load and efficiency are used to estimate energy reduction from a scheduling measure.



	A	B	C	D	E	F	G	H	I	J	K
1	Assumptions		North AHU								
2		units	Base	ECM							
3	Supply fan flow rate	cfm	40,000	40,000	From drawings						
4	Heating plant efficiency	%	80%	80%	From drawings						
5	airflow factor		60%	60%	Engineering estimate						
6											
7	Calculations										
8	Dry-bulb outside air temperature, °F	Occupied operation bin hours (M-F 6a-10p, Sa 7a-5p)	SAT setpoint, (F)	Baseline SAT due to leakage, (F)	Baseline Load from leaky valve, (Btuh)	Baseline Heating energy waste, (Btu)	ECM SAT after leakage is repaired, (F)	ECM Heating Energy Waste (Btu)	Chiller efficiency, (kW/ton)	Chiller energy savings, (kWh)	
9	89	1	70	78	207,360	207,360	70	0	0.57	9.8	
10	87	4	70	78	207,360	829,440	70	0	0.57	39	
11	85	11	70	78	207,360	2,280,960	70	0	0.56	107	
12	83	10	70	78	207,360	2,073,600	70	0	0.56	97	
13	81	34	70	78	207,360	7,050,240	70	0	0.55	325	
14	79	45	70	78	207,360	9,331,200	70	0	0.54	423	
15	77	38	70	78	207,360	7,879,680	70	0	0.54	352	
16	75	157	70	78	207,360	32,555,520	70	0	0.53	1,431	
17	73	322	70	78	207,360	66,769,920	70	0	0.52	2,876	
18	71	382	70	78	207,360	79,211,520	70	0	0.53	3,511	
19	69	430	70	78	207,360	89,164,800	70	0	0.57	4,265	
20	67	526	70	78	207,360	109,071,360	70	0	0.65	5,889	
21	65	470	70	78	207,360	97,459,200	70	0	0.76	6,147	
22	63	516	70	78	207,360	106,997,760	70	0	0.90	8,050	
23	61	450	70	78	207,360	93,312,000	70	0	1.09	8,447	
24	59	219	73	78	129,600	28,382,400	73	0	1.31	3,091	
25	57	347	76	78	51,840	17,988,480	76	0	1.54	2,315	
26	55	389	79	79	0	0	79	0	1.66	0	
27	53	151	82	82	0	0	82	0	1.85	0	
28		4502				750,565,440	Btu			47,376	kWh
29						9,382	therms				

In this example, a leaking hot water valve on an AHU is causing unnecessary chiller use.

Many common EBCx measures are dependent on weather and schedule. These calculations lend themselves to using bin and 8760 calculation methods, which provide relatively simple and flexible approaches to capture the dynamic nature of buildings in the savings calculations. Both of these approaches are especially conducive for weather dependent operations. These are the approaches needed for estimating peak Demand Savings.



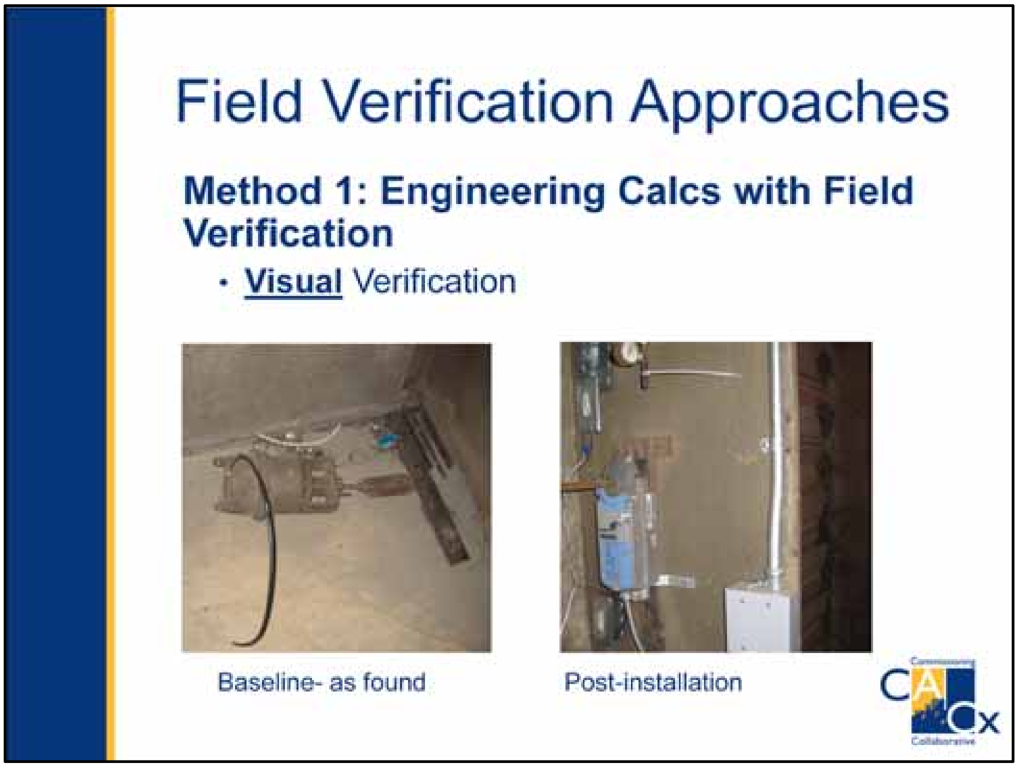
Method 4 of this guide and Option D of IPMVP cover calibrated energy simulations. These computer models using software such as eQUEST of Energy Plus are tuned to match the energy use of the building.

Un-calibrated simulations are occasionally used in EBCx projects, but often cannot simulate malfunctioning or non-optimal
systems. These non-optimal systems are typically the bulk of identified EBCx measures, so simulations should be used with great care. Advanced users can sometimes provide work-arounds to mimic actual conditions; if used, these strategies must be well documented. In these cases, the third party reviewer should have similar expertise.

Un-calibrated simulations may produce results that do not represent the actual performance of the project site. As with all calculations, the accuracy of the savings estimates improve with the level of field data used. System level data can be used to enhance the accuracy of simulations.

With Method 1, baseline field data should be collected to demonstrate the original baseline performance and show the performance deficiency that is the basis for the recommended ECM. Performance data along with the inputs and any adjustments used in the simulation typically cover the documentation requirements of Method 1.

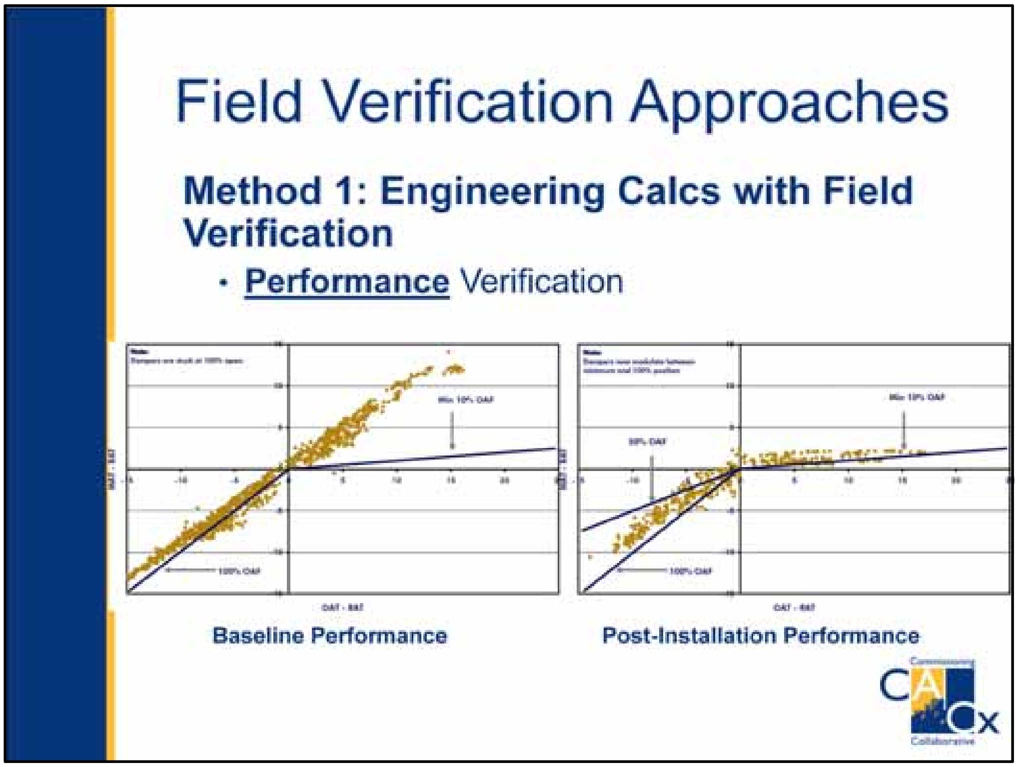
For more certainty when using simulations, refer to Method 4 in the guideline, which describes the use of calibrated simulations.



Method 1 discusses the two primary performance verification strategies: visual verification and operational performance verification.

Visual verification is a low rigor/low cost approach that proves the operational features of a measure are functioning properly. Since visual verification provides only a snap shot of current operation, it should only be used in low risk situations, such as low savings measures. The photos shown here are the disconnected damper actuator as found in the baseline period and the new actuator that was installed to regain control of the outside air dampers after the EBCx investigation.

Remember, for savings verification, you want to demonstrate the measure will actually produce savings across a range of operating conditions. In the example photos above, simply showing a new damper is installed may not demonstrate the predicted savings are achieved. As Steve Schiller always said, this type of verification proves the ECM's "potential to perform". To increase the certainty of visual verification, especially for complex measures such as an economizer, additional steps should be taken to prove the new actuator functions as expected.

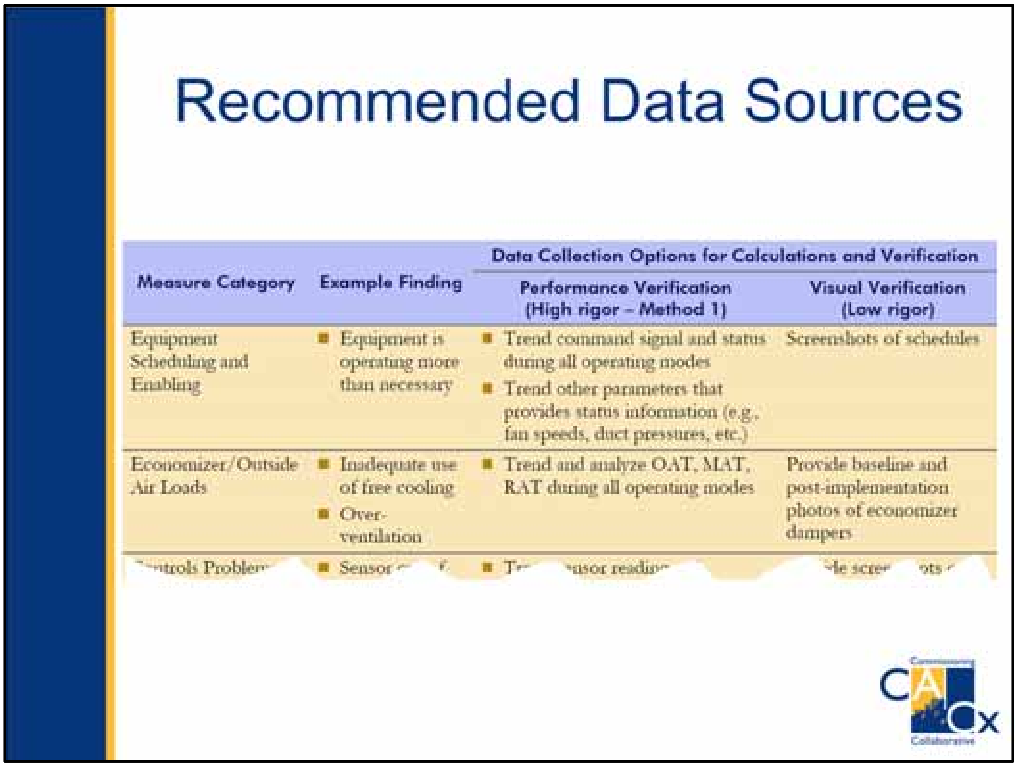


Operational performance verification provides more certainty in the resulting energy savings claims and is the recommended minimum level of effort for higher risk savings EBCx projects. Method 1 requires this type of verification.

As the name suggests, performance verification includes collection of data that proves the "operational performance" of the equipment in question. Functional performance tests and data trending over typical operating conditions are the most common forms of data collection for this field verification approach. Method 1 requires operational performance verification to help ensure results.

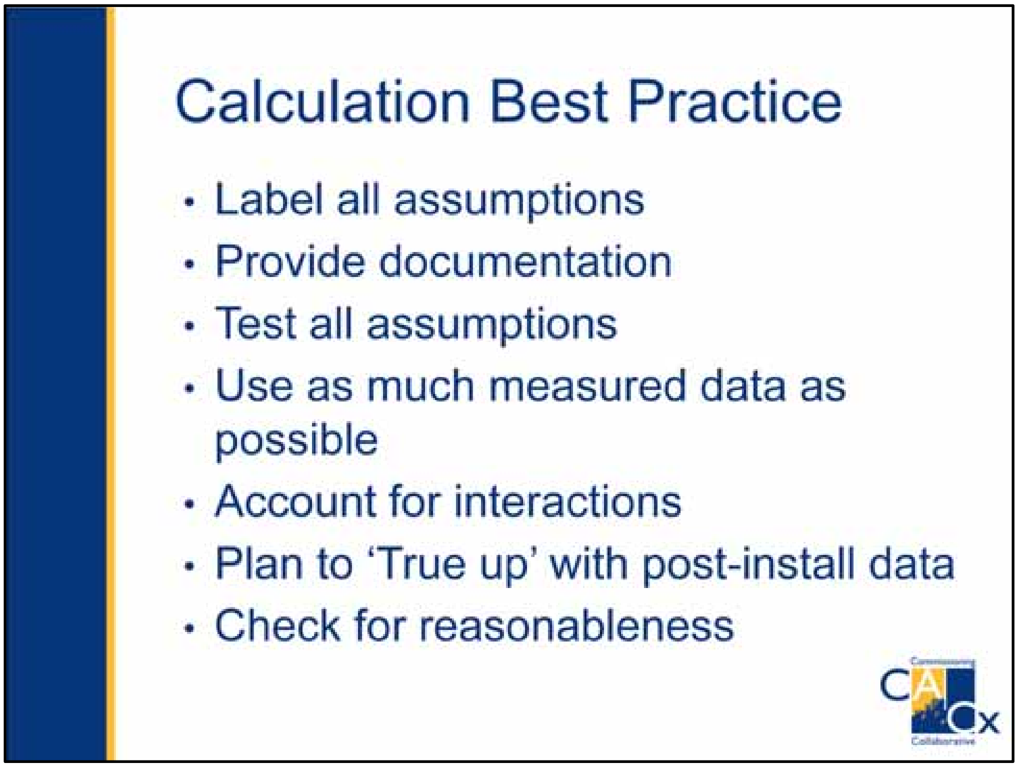
Performance verification is still limited due to a focus on operational verification and not savings verification. Remember, proving the impact of an ECM does not necessarily guarantee its predicted energy savings exist or will last.

In the example above, the economizer performance is shown in the baseline and post installation cases. This strategy of using a scatter plot of OAT-RAT vs. (MAT-RAT) is very effective in showing outdoor air levels.



The guideline presents recommended field data collection strategies for various measure categories including: equipment scheduling, economizer repairs, controls optimization and efficiency improvement/load reduction.

For each measure category, both high and low rigor options are presented. You should chose the approach that best meets the requirements of your project. Remember, higher risk or more regulated projects, such as utility EBCx programs, prefer performance verification approaches for more certainty that the estimated savings have been achieved. For this reason, operational performance verification is also required to fulfill "Method 1."



Since there is such a large range in potential accuracy when using engineering calculations to estimate energy savings, this guide presents a few best practices to ensure a high level of quality of the calculations.

The first two of these best practice strategies are for clarity in presentation of the calculation for review and documentation. The others are focused on ensuring savings estimates are as accurate as possible.

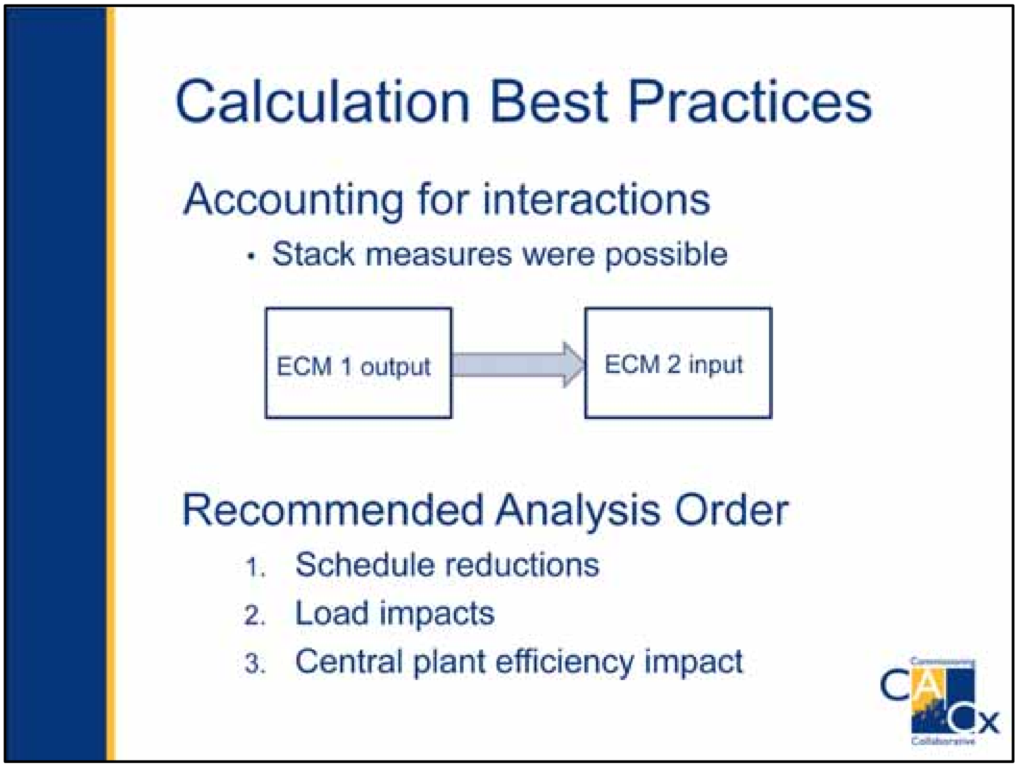
For example, "testing all assumption": testing any assumed values over a range of potential values for impact on the final savings results can help to identify assumptions that have a significant impact on savings estimates. This testing can indicate where assumptions are inappropriate, and measured values should be used.

Using measured data over a period of time rather than nameplate or design values improves accuracy, especially for systems that have a high variation in energy use.

Designing the calculations for easy correction if post-installation conditions are different than expected will save effort;

checking resulting savings estimates for reasonableness is always important. Approaches such as conducting an energy balance on the building to ensure predicted energy use and savings are reasonable can help identify issues.

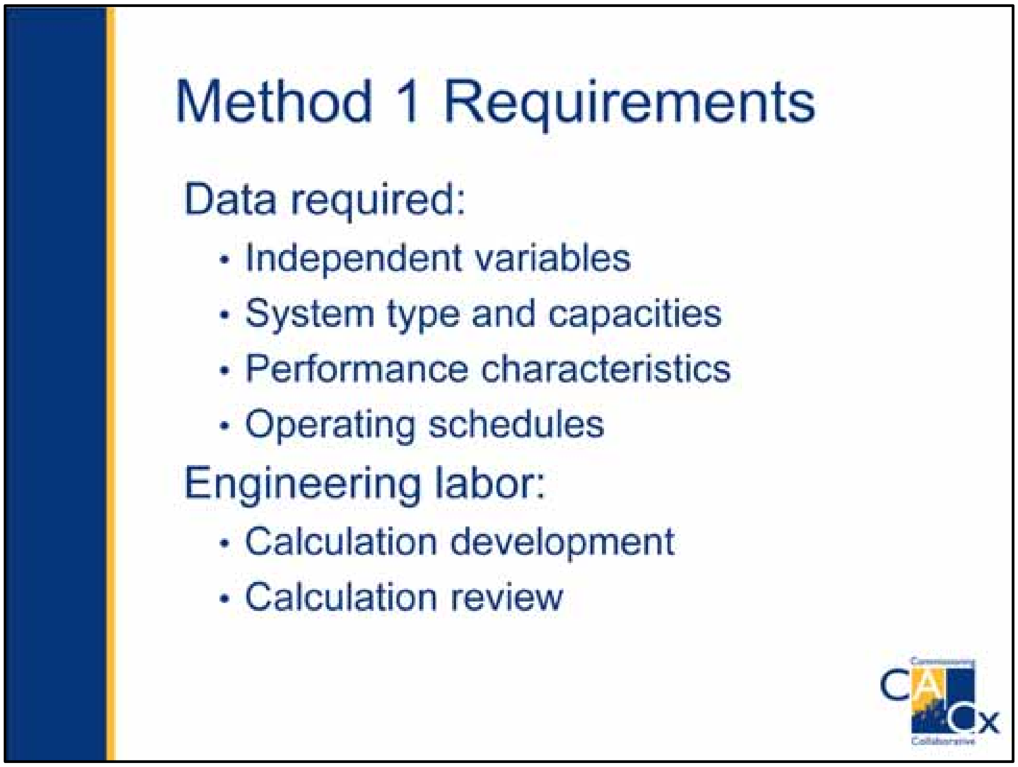
More complicated is accounting for interactions between measures.



When multiple interactive measures are identified and investigated during an EBCx project, it's important to ensure savings estimates are not double counted. When interactions between measures are present, the engineer developing the calculations must manually account for these impacts. Stacking the measures where the outputs of one are used as the inputs of the next is one approach that can address potential interaction. This approach is especially applicable in utility sponsored programs where energy savings (even on one system) must be separated out into individual ECMs.

Typically, ECMs affecting the same or interactive equipment should be considered in the following order: reduced operating hours, changes to loads, and central plant equipment efficiency. For example, scheduling measures are considered first so subsequent measures are not counted when the equipment is off.

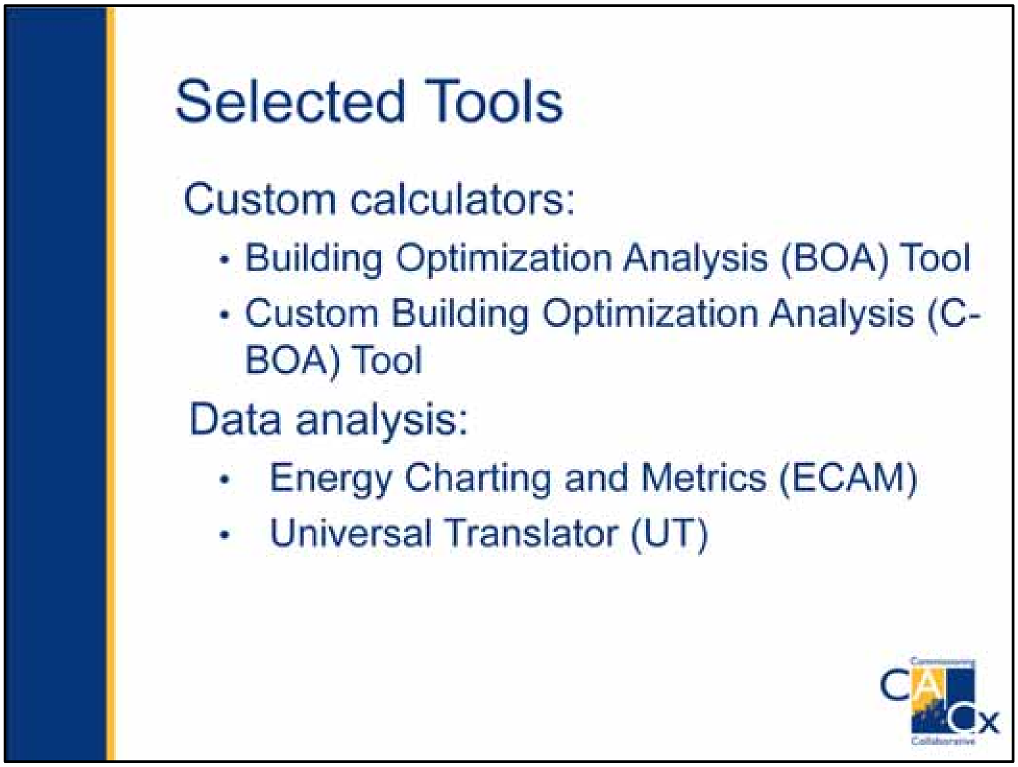
Assessing interactive measures can be difficult, and improper stacking of ECMs can overstate savings estimates. Stacking strategies can vary, and should be carefully considered based on the ECMs being analyzed. To access the integrated effects of ECMs, an energy simulation program can be useful.



One of the key elements of this guideline is incorporation of the measurement and verification strategy into the EBCx process. By considering the process as a whole, field data collection, energy calculations, and verification activities are coordinated.

The Method 1 data requirements are within the normal realm of EBCx data collection. Typical data collected includes independent variables that drive heating and cooling loads (such as outdoor temperatures), system and equipment specifications, and operating schedules. The amount of data required will depend upon the amount of variation in equipment operations. Variable loads with complex systems require more data to assess the expected range of operations than simple constant load equipment.

The engineering labor for calculation development and review must have the required expertise in energy analysis.



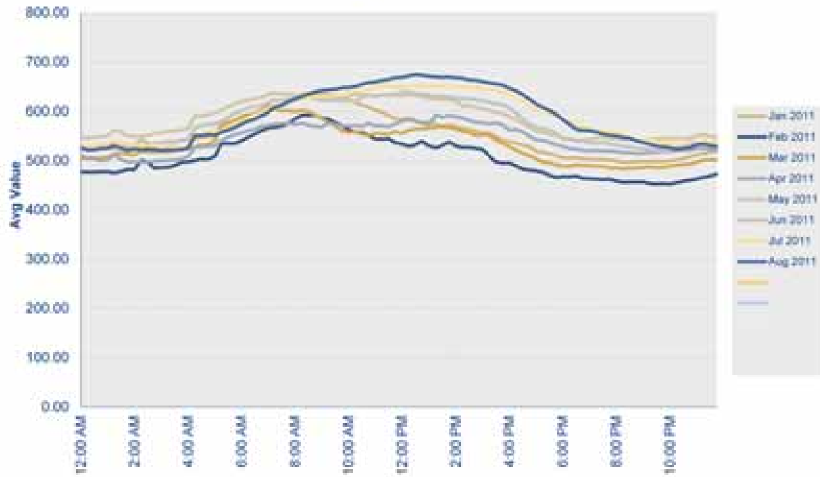
There are a number of tools that are publically available that can augment Method 1 approach to energy savings. For example, California utility EBCx programs have EBCx calculators, BOA and C-BOA.

Data analysis tools that can also be useful include ECAM and UT.
ECAM is an Xcel add-in that provides data visualization of energy use, and allows for inclusion of other variables such as occupancy. (CCC tool) A new version of this tool was released on the CCC website recently.
UT is a tool that helps align data from multiple sources that may be in different time increments. (PG&E) A new release of this tool is upcoming.

These and other resources are documented in Appendix C of the guide.

The BOA, C-BOA and ECAM tools can be found here, http://cacx.org/resources/rcxtools/spreadsheet_tools.html#energy_savings_calculation_tools.
Universal Translator can be found here, http://utonline.org/cms/.

ECAM Example



Where to find the Guideline

- http://cacx.org/resources/vos-guidelines/

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!

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