MBCx Project Guidelines and Minimum Requirements

Monitoring Based Commissioning (MBCx) Program
2010-2015 Higher Education / Investor Owned Utility (IOU) Partnership Programs

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The Higher Education / IOU Partnership offers incentives for implementing MBCx projects at buildings or central plants at UC, CSU, and CCC campuses. MBCx is a unique combination of whole-building monitoring and retro-commissioning. The monitoring supports the retro-commissioning effort by providing a diagnostic tool, as well as by documenting energy savings in the near term and increasing savings persistence over the long term.

Below is an outline of the general MBCx process, with additional details and program requirements listed in subsequent sections.

Planning Phase

- Hire a Cx agent and/or designate an internal team to identify and implement MBCx projects.
- Benchmark campus buildings and identify the best candidates for the MBCx program.
- Submit a project application to the Partnership for each project to be implemented.

Investigation Phase

- Install all metering, EMS, and EIS components necessary to trend whole-building energy use.
- Collect baseline energy use data (typically 3 months) and calculate annual energy use.
- Evaluate building and trend operating points through EMS to identify operational deficiencies and energy efficiency opportunities.
- Submit a Baseline Report to the Partnership detailing baseline energy use.

Implementation Phase

- Implement identified energy efficiency measures.
- Verify proper measure installation and building systems operation through trending.
- Collect post-project energy use data (typically 3 months) and calculate annual energy use.

Reporting Phase

- Submit a Final Report to the Partnership detailing which EEMs were implemented, post-project annual energy use, and annual energy savings (see below for additional requirements).
- Train campus staff in the revised operating sequences and functionality of building systems.
- Receive an incentive payment based on the amount of energy saved.

To participate in the Partnership's MBCx program, the campus must take either electricity or natural gas service from an IOU (though commodity electricity or gas may be purchased from a supplier other than the IOU). The campus must also commit to implementing all no-cost and low-cost measures identified during the MBCx project that it agrees are feasible. Finally, in addition to these Guidelines, campuses must meet IOU documentation and process requirements specific to each IOU's program implementation.

Incentives for the MBCx program are one-time payments of $0.24/ annual kWh and $1.00/annual therm saved, capped at 80% of verified project costs. Although no incentive is paid for peak demand (kW) savings, the Partnership requires that an analysis of peak demand savings be submitted.

Figure 1 - MBCx Process Schedule and Deliverables

Process Step	**Deliverable**
Planning Phase	
Hire Cx Agent and/or designate internal MBCx team	
Benchmarking / project selection	Form C-1 (mandatory for UC only)
Submit project application	Form C
Partnership reviews and approves application	
Campus signs Campus Payment (UC/CSU) or Project Agreement (CCC) form	Campus Payment (UC/CSU) or Project Agreement (CCC) form
Investigation Phase	
Install whole-building metering, connect meters to building/campus EMS/EIS	
Calibrate and document whole-building meter calibration	Meter Calibration Documentation
Collect whole-building trend data (typically 3 months)	
Perform building evaluation	
Determine baseline annual energy use based on whole-building energy trends	
Submit Baseline Report to Partnership	Baseline Report, baseline energy analysis
Campus emails list of measures to be implemented to Partnership	
Partnership reviews and approves baseline analysis	
Implementation Phase	
Implement identified EEMs	
Campus emails log of implemented MBCx measures to Partnership	MBCx Measure Log
Verify proper EEM implementation	
Collect whole-building trend data (typically 3 months)	
Reporting Phase	
Determine post-implementation annual energy use based on whole-building energy trends	
Submit Form E, verifying project completion	Form E
Submit Final Report and associated documentation to Partnership	Final Report, post-MBCx energy analysis, Form D, Cost Documentation, Systems Manual (if applicable)
Perform staff training	
Receive incentive payment	

Planning Phase

<u>Hire a Cx Agent</u>

Campuses do not have to hire a Commissioning (Cx) Agent (projects can be performed by in-house staff), but the Partnership recommends doing so, as Cx Agents will have experience and expertise that most campus staffs do not.

Campuses can choose to hire a Cx Agent either before or after the benchmarking process. If the campus has enough information available to them through existing metering or knowledge of current building operations, they may be able to identify good candidates for the MBCx program on their own. Alternatively, a Cx Agent can survey campus buildings and help to identify these candidates.

In most cases, if the campus is planning to hire a Cx Agent, the Partnership will not accept project applications before a contract is in place. This demonstrates a commitment to the project by the campus and helps to ensure project continuity.

Benchmarking/Project Selection

UC campuses are required to submit the program's Form C-1, which identifies the largest campus buildings and their energy use. This benchmarking tool helps to determine priorities for MBCx project implementation. CSU and CCC campuses are not required to submit this form, but are encouraged to use it, or complete some type of formal benchmarking process.

Additional guidance for selecting MBCx projects can be found in Attachment 1.

Project Application

The Cx Agent or campus must fill out and submit a project application, also referred to as the Form C. The Form C will contain information on the building's HVAC systems, current and proposed metering/Energy Management System (EMS)/Energy Information System (EIS), project budget, and estimates of baseline annual energy use. The Form C estimates of baseline energy use can be based on existing building metering, prorated campus energy use, or generic Energy Use Intensity (EUI) values (e.g. *California End-Use Survey* (*CEUS*)). MBCx projects will typically use the Retrofit Add-on (REA) category rather than a replace on burnout (ROB) or early retirement (RET) classification.

UC and CSU campuses will submit and periodically update a project schedule through the Partnership's P6 tracking tool. CCC campuses will submit a project schedule within the Form C and should notify the Partnership of changes in project schedules.

The Form C is then submitted to the Partnership for approval by the Management Team. It is important that the campus *not* implement any Energy Efficiency Measures (EEMs) or purchase any equipment prior to Management Team approval. EEMs implemented prior to approval may result in decreased incentives and equipment purchased prior to approval may result in disallowed project costs, which may ultimately lead to a lower incentive, if cost-capped.

Campus Payment/Project Agreement Form

Once the Partnership reviews and approves the project application, the campus will sign a project-specific agreement in which the utility agrees to pay the campus an incentive based on their delivered energy savings. For UC and CSU campuses this form is called the Campus Payment form. For CCC campuses, this form is called the MBCx Project Agreement. The Partnership reserves the right to perform a pre-inspection of the building.

Investigation Phase

Metering

The program requires whole-building energy use metering. This means that all energy sources (excluding small energy flows, such as gas service only for Bunsen burners or Domestic Hot Water (DHW)) entering and leaving a building or central plant (CP) must be metered. The program's primary requirement for meters is that actual interval energy use (hourly or smaller) be automatically transmitted to a front-end EMS or EIS where real-time energy use can be monitored and stored. Metered energy use includes electricity and other utilities the building receives, such as chilled water, hot water, steam or natural gas.

Existing meters which are not tied into the building's EMS/EIS may fulfill the metering requirement if they are calibrated and connected to the EMS/EIS using new pulse outputs. Proper calibration of existing meters and proper EIS operation should be confirmed at the very beginning of a project so that no data is lost. Documentation verifying that the meters were calibrated within one year of the start of the MBCx project is to be submitted to the Partnership, as part of the project documentation in printable form, prior to start of the baseline trending period.

Installation of sub-meters within a building may be desired by the campus in order to isolate lighting or plug loads or to break out particular equipment energy use. Sub-metering of cogeneration systems within a central plant may be necessary to determine individual system efficiencies.

Campuses should also consider metering domestic water use for comprehensiveness, though this is not required by the program[1].

For additional information on metering best practices, see Attachment 2.

Whole-building energy trends will be used to calculate baseline and post-MBCx annual energy use. See the Measurement and Verification (M&V) section below and Attachment 3 for more details. Baseline energy use is defined as the energy the building is using historically. It is not adjusted for Title 24 standards or for the remaining useful life of the equipment.

Energy Management System (EMS) / Energy Information System (EIS)

The building (or campus) should have a functioning EMS which is, at a minimum, capable of controlling, monitoring and trending building equipment. Ideally the EMS will have much greater granularity in its control capabilities and will also be capable of triggering alarms as systems drift from their designed operating conditions.

The campus must also utilize an EIS specifically designed for the tracking and evaluation of energy use meters and EMS points. The EIS should have the ultimate capability to log, store, and manipulate energy use information for every major building on campus for at least 10 years. It is possible that an advanced EMS could provide the energy use tracking functionality that normally requires an EIS.

Building Evaluation

While baseline energy trends are being collected (see M&V section for trending duration information), the Cx Agent should be performing a building evaluation to identify operational deficiencies and energy efficiency opportunities. Evaluation typically includes trending critical parameters, reviewing operations with plant engineers, investigating operating schedules and sequences of operations, and physically observing building operations. Any points trended for analysis should be calibrated to ensure proper results. The operation of any critical valves, dampers, VFDs, etc. should be verified through trending or functional testing.

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[1] The CPUC and IOUs are conducting pilot water-energy programs. Eligibility of water-energy savings for Partnership incentives is subject to the guidance provided by CPUC.

Additional information on typical systems evaluated under MBCx and measures identified for implementation can be found in Attachments 5 and 6, respectively.

Measurement and Verification (M&V)

The MBCx program is based on measuring whole-building energy use. Accordingly, the program requires, except as noted below, the use of an IPMVP[2] Option C-type energy analysis to determine baseline and post-MBCx annual energy use. The program does not, however, require strict adherence to IPMVP protocols due to the long (12 months or greater) trending periods required.

In order to create accurate energy models, at least three consecutive months (not including January or July) of baseline and post-implementation whole-building energy trends are requested. The purpose of this requirement is to ensure that energy use is trended over a period which captures a range of independent variables (typically outside air temperature) representative of most of the annual operating conditions. More than three months of data may be required to create acceptable model correlations. (Note that January and July data can and should be used in the energy analyses if available; those months just do not count toward the *three consecutive month* requirement.)

M&V approaches other than IPMVP Option C (i.e. Options A, B, or D) will only be considered if circumstances preclude the use of Option C. Such circumstances may include low expected energy savings (<10%) or the loss of either baseline or post-MBCx energy trends. The use of alternative M&V methods must be approved by the Partnership.

Additional M&V information and requirements can be found in Attachment 3.

Energy Models

An MBCx program best practice is to create whole-building energy models. One good modelling tool is the Universal Translator 3 (UT3) and its M&V Module. Equest is another good choice for creating a whole building model.

The UT3 M&V tool allows the user to quickly develop and evaluate the accuracy of empirical models that are based on short-time interval energy use and independent variable data. It allows users to estimate annual energy use and savings from short periods of measured data. The UT3 M&V tool provides the user with an interface to vary model input parameters (including analysis time interval, amount of data), modeling algorithms (temperature and time-of-week, temperature only, time only, simple average, number of line segments), and data filtering (occupied/unoccupied periods, weekday/weekend/holiday) in an effort to develop the most accurate energy models possible. The energy models are used to adjust baseline and/or post-installation energy use to a common set of conditions, usually defined by the dry-bulb ambient temperature from a TMY3 weather file. The UT3 M&V tool allows export of all data streams as well as model goodness-of-fit and uncertainty metrics. Stakeholders may set minimum requirements for modeling, such as the minimum number of points per model, the maximum allowable CV, and so on.

[2] International Performance Measurement and Verification Protocol

See Attachment 4 for more details about UT3 and the requirements of other analysis tools.

Baseline Report

A Baseline Report is to be submitted to the Partnership which includes, at a minimum, the baseline energy analysis. The Baseline Report will also include a description of the facility, HVAC equipment, controls, operating schedules, operational deficiencies and energy efficiency opportunities (commonly referred to as a Findings Log), and a verbal and visual description of the analysis approach. All raw energy trend data used is to be submitted along with live versions of any spreadsheet or other analyses. The Baseline Documentation Approval Form should be submitted with documents mentioned above. The Partnership may request additional information if it is deemed necessary to fully evaluate baseline conditions.

See Attachment 11 for details about the Baseline Documentation Approval Form.

At this stage the Implementer should also comment on revised energy savings estimates due either to differences between the original baseline estimate and the measured baseline energy use or to revised percentage savings estimates based on new information gained from the building investigation.

Although no incentive is paid for peak demand (kW) savings, the Partnership requires that an analysis of peak demand savings be submitted in accordance with the DEER Peak Demand definition used by the MBCx program (Attachment 7). A determination of baseline peak demand should be made at this point.

A sample Baseline Report outline can be found in Section 1 of Attachment 8.

Partnership Approval of Baseline Energy Use

The Partnership will review and approve the submitted baseline annual energy use. The campus is to wait for Partnership approval before beginning MBCx measure implementation in case the collection of additional trend data is deemed necessary. The Partnership will send a completed Baseline Documentation Approval Form as notice to proceed with implementation. Savings and incentive estimates may be revised at this stage to be consistent with the approved baseline should it differ from the estimated baseline provided in the project application. Failure to wait for Partnership approval could result in reduced energy savings and incentive.

See Attachment 11 for details about the Baseline Documentation Approval Form.

Building Operations Log

A log of changes to the building's operation should be maintained throughout the life of the MBCx project, starting the same date the baseline trending period begins, and continuing for the following five years after the completion of the project. The log should include any major changes to the building's operation, including: major scheduling changes, major equipment replacements, building remodels or additions, retrofit projects, etc.

See Attachment 10 for a sample Building Operations Log

Implementation Phase

Implement Identified EEMs

Either the campus, Cx Agent, or another company implements the identified EEMs. No other projects which will receive a utility energy incentive should be implemented in the building during the MBCx project. This includes the period from the beginning of baseline trending to the completion of post-MBCx trending. If other projects are implemented at the same time, their calculated savings will be subtracted from the measured MBCx savings to determine the net effect of the MBCx project.

Track MBCx Measure Implementation

The campus or Cx Agent should log each MBCx measure that is implemented as part of the MBCx project. The log should be submitted with the final MBCx report.

See Attachment 9 for a sample MBCx Measure Log.

Verify Proper EEM Implementation

The campus or Cx Agent should verify that all chosen EEMs have been implemented properly. This can be done by evaluating whole-building or sub-system energy use trends, or through EMS trending.

Post-Implementation Data Collection

Once all measures have been verified as implemented, the post-implementation energy use trending period begins.

Reporting Phase

Post-Implementation Measurement and Verification

The determination of post-implementation annual energy use is subject to the same requirements listed above in the Measurement and Verification section.

Form E

Once the project has been completed, all measures have been verified as being properly implemented, and a final determination of energy savings has been made, a Form E is submitted to the Partnership.

Final Report

A Final Report must be submitted to the Partnership which includes include a description of the facility, HVAC equipment, controls, operating schedules, operational deficiencies and energy efficiency opportunities (commonly referred to as a Findings Log), changes in project scope, an analysis of baseline and post-MBCx energy use and the resulting energy savings along with a verbal and visual description of the analysis approach, and any other issues encountered which are relevant to a comprehensive understanding of the project. The Final Report should also describe the staff training program which will be offered and when it will take place.

A sample Final Report outline can be found in Section 2 of Attachment 8.

Form D

The Form D is a spreadsheet campuses must submit to the Partnership along with the Final Report which summarizes building systems, baseline and post-MBCx energy use and savings, and project costs.

Cost Documentation

Project cost documentation must be submitted by the campus and/or the Cx Agent. All contractor costs must be verified with copies of paid invoices. In-house labor and materials can be included in the total project cost and should be verified using campus accounting software. Equipment purchased prior to receiving application approval from the Partnership Management Team cannot be included in the project cost.

Incentive payments are cost-capped based on 80% of verified project costs, so it is important to properly document as much of the project cost as possible.

Systems Manual

The Systems Manual is a comprehensive compilation of documents which fully describe, among other items, the building's operating systems, controls sequences, maintenance schedules, and diagnostic protocols. It is recommended that the campus contract with their Cx Agent to provide this documentation, however it is not a program requirement. If the cost of creating a Systems Manual is included in the project costs, a digital copy of the Systems Manual must be submitted to the Partnership.

A sample Systems Manual outline can be found in Section 3 of Attachment 8.

Staff Training

All campus staff responsible for maintaining the building should be trained in the current (post-MBCx) operating sequences. Staff should also be trained to utilize the EMS and EIS to recognize equipment and system failures and be able to diagnose the cause of the problem.

Partnership Approval and Incentive Payment

Upon receipt of all required final documentation (Final Report, post-MBCx energy use analysis, Form E, Form D, and cost documentation), the Partnership will perform a review of the energy savings calculations. If it is found that the analysis has errors or that the energy trends collected are insufficient to support the claimed savings, corrections and/or the collection of additional trend data may be requested. Once energy savings have been approved, they will be submitted to the IOU for processing of an incentive payment.

Other Considerations

Concurrent Energy Efficiency Projects

The campus should not implement other energy efficiency projects which will overlap with the MBCx project. Because the energy savings from an MBCx project are based on actual trended whole-building energy use, any other projects implemented within the bounds of baseline and post-MBCx trending will be captured by the MBCx project. This is only of concern for energy efficiency projects which will attempt to claim an incentive outside of the MBCx project.

End-of-the-Year Protocol

Because campuses and IOUs commit to achieving certain energy savings goals each year, there is usually a rush to complete projects at the end of the year. Unless otherwise notified, the deadline for submitting all documentation necessary for a final review will be November 15th. The desire to complete a project in a given year does not alone justify the use of less than three months of pre- and post-project trend data. Each project will be considered individually and in accordance with the guidelines in the Measurement and Verification section above and in Attachment 3 as to whether or not this requirement can be waived.

Alternative Approaches for Small Buildings

The MBCx process is ideally suited for buildings over 25K ft^2. Because meter costs do not scale proportionally with building size, the cost to add multiple meters to some smaller buildings can be prohibitive. The following alternative approaches will be considered on a case-by-case basis by the Partnership for small buildings.

Option 1: Electrical Meter Only

Buildings smaller than 25K ft^2 which do not use significant amounts of CHW, HHW, steam, or gas may only be required to install an electric meter in order to participate in the MBCx Program. This option should be discussed with the Partnership to determine eligibility.

Option 2: Grouping of Buildings

A collection of buildings smaller than 25K ft^2 which share CHW, HHW, steam, or gas distribution lines may qualify to be metered and claim energy savings as a group. Each building is required to have its own electric meter. This option should be discussed with the Partnership to determine eligibility.

Option 3: Central Plant and Connected Buildings

A traditional central plant (CP) MBCx project only claims energy savings from efficiency improvements made at the CP. If a CP serves a group of buildings smaller than 25K ft^2, you may be able to claim both efficiency and load reduction energy savings through CP metering. Under this option, the CP would need to have all energy sources entering and leaving metered, but the connected buildings would only need to have electric meters installed. The CP and connected buildings all need to undergo a retrocommissioning process. This option should be discussed with the Partnership to determine eligibility.

List of Attachments

Attachment 1 – Selection Guidelines for MBCx Sites

The following criteria should be used when selecting good candidate sites for MBCx projects:

- Buildings should have 25,000 square feet of conditioned space or larger. Clusters of multiple, similar buildings located near each other may be considered in order to increase the footprint impacted by MBCx.
- Buildings should have some type of mechanical air-conditioning; either served by DX units, dedicated chillers, or chilled water from a central plant.
- Select buildings with high suspected baseline energy use.
    - Buildings with laboratories using fume-hoods, or other spaces requiring elevated ventilation
    - Buildings with data centers
    - Buildings with extended operating hours and/or dense occupancy
    - Where pre-existing metering exists, any building shown to exhibit above average use per square foot
- The MBCx process can be applied to central plants, when there are suspected energy savings opportunities there. Monitoring will need to be applied to the central plant's energy outputs (chilled water, hot water, steam) as well as its inputs.
- Buildings should have functioning control systems such that energy conservation measures can be implemented and expected to persist.

Conversely, the following types of sites make poor candidates for MBCx projects:

- Small buildings
- Buildings with limited annual operating hours
- Buildings with low occupancy
- Buildings that are only served by heating and ventilation (or evaporative cooling), with no mechanical air conditioning
- Buildings with non-functioning control systems
- Buildings already operating efficiently, with low energy use intensities (kWh/yr/sf, th/yr/sf)
- Buildings with strict operating requirements, that would prevent modifications being made for efficiency purposes
- Buildings with upcoming major renovations
- Buildings with pneumatic controls

Attachment 2 – Metering Guidelines

*The following information is presented to outline metering best practices. These **do not** represent program requirements.*

A robust guide for selection of appropriate metering and data storage devices and analysis tools for use under the MBCx Program can be found in the United States Federal Energy Management Program (FEMP) document, *Metering Best Practices: A Guide to Achieving Utility Resource Efficiency, October 2007*. The most relevant information can be found in Chapter 5 "Metering Technologies", Chapter 6 "Metering Communications and Data Storage", and Chapter 7 "Data Analysis and Use". This document can be found online at http://www1.eere.energy.gov/femp/pdfs/mbpg.pdf.

Below are some relevant highlights from the FEMP metering guide. **Campuses should discuss their particular circumstances with a vendor to determine which metering solutions will best meet their needs.** Campuses should also bear in mind that installation costs for any given meter can vary greatly depending on size and other physical constraints, and can often cost more than the metering equipment itself.

Electricity Metering

There are two basic types of electrical meters, mechanical and digital meters. Mechanical meters are an older technology and represent the majority of the installed base. Mechanical meters may or may not have electronic pulse outputs to automatically transmit energy use data to an EMS or EIS. Digital (advanced) meters are the new standard in electrical metering and provide many additional features over mechanical meters. Some of these features include increased accuracy, on-board data storage, variable data reporting intervals, alarming capabilities, multiple communication modes, and various energy-use statistics.

Equipment costs for mechanical meters with pulse outputs range from $200 to $400. Equipment costs for digital meters range from $1,000 to $3,000.

Flow Metering for Natural Gas, Steam, CHW, and HHW

Flow metering applications use three main types of meters: positive displacement, differential pressure, and velocity. Within each of these categories there are several different metering options, each with pros and cons. Campuses should pay particular attention to the turndown ratio (range of operation) of a meter and whether or not it will meet the full range of their metering needs.

Natural Gas Metering

Special considerations for the metering of natural gas include whether or not the meter will also measure gas temperature and pressure along with flow. If temperature and pressure are not directly measured, alternative options include placing a pressure regulator upstream of the meter and calibrating the meter to a particular pressure, and possibly just assuming gas temperature.

Natural gas meters can range from $150 for a diaphragm positive displacement meter (medium turndown ratio, medium pressure losses) to $6,000 for a vortex shedding velocity meter (high turndown ratio, low pressure losses).

Steam Metering

The measurement of steam energy usage is accomplished with either a steam meter (measuring steam flow into a building) or a steam condensate meter (measuring the flow of condensed steam leaving the building). The cost for steam meters is higher than for condensate meters, but a steam meter will capture the total steam energy use of a building, including vented steam, condensate leaks, and direct steam uses.

Steam meters can range in cost from $500 for a turbine velocity meter (medium turndown ratio, medium pressure losses) to $6,000 for a vortex shedding velocity meter (high turndown ratio, low pressure losses). Condensate meters can range from $4,000 to $7,000, depending on type, size, communication capability, and accuracy.

Attachment 3 – Measurement and Verification Guidelines

As mentioned in the Measurement and Verification section of the main document, IPMVP Option C is the preferred M&V method for MBCx projects and should be used whenever possible and appropriate. Using alternative M&V approaches requires approval from the Partnership.

Option C – Whole Facility

Length of Trend Periods

1. IPMVP Option C entails creating energy use models for each metered utility entering a building using whole-building interval trend data. The program does not require "adherence" to IPMVP guidelines, as the IPMVP baseline and post-implementation trending periods are generally longer than is practical for the purposes of the MBCx program (12 or more months). Instead, the program nominally requires that a minimum of three consecutive months of baseline and post-MBCx trend data, not to include January or July, be collected for each utility. January and July are typically extreme weather months with some time spent without classes in session. Therefore, they should not be included as one of only three months of data, but they should be included if three additional months of data has been collected.

The spirit of the three-consecutive-months requirement is to ensure that energy trends are captured over a full range of the independent variables (IVs) to which they are correlated. If there is a distinct need to shorten the trending period and it can be shown that sufficient data points have been collected over a representative span of IVs prior to three months, the three-consecutive-months requirement may be waived by the program.

If whole-building monthly or annual energy use is available in the baseline period (prior to installing whole-building interval meters), one month of interval trend data may be able to be used to create an energy model if the model's annual energy use is shown to be in-line with the historical energy use.

Energy Use Correlation

An Option C analysis involves correlating energy use (usually at either hourly or daily intervals) to one or more IVs and then extrapolating to annual energy use based on typical or normalized IV values over an entire year. The most common IV used is outside air temperature (OAT). Other IVs include, but are not limited to, building occupancy, daily operating hours, and Time-of-Day.

There are three metrics identified in the IPMVP and ASHRAE Guideline 14-2002 for use in evaluating the correlation between energy use and an IV which should be reported for all regression analyses: The coefficient of determination (R^2), the coefficient of variation of the root mean square error (CV-RMSE), and the t-statistic.

All three metrics should be reported as part of an analysis whenever applicable. Regression models will not be strictly held to the acceptance criteria/guidelines given below, but attempts should be made to optimize their values where possible. Additional information on these metrics can be found in Appendix B of the IPMVP (EVO 10000 – 1:2010) and Section 5.2.11 of ASHRAE Guideline 14-2002.

R^2: The coefficient of determination (R^2) is the most commonly used metric for determining whether or not a regression correlates to an IV, however a model should not be accepted nor rejected based on this

metric alone. High R^2 values indicate that energy use is very dependent on an IV. A low R^2 means that energy use is not very dependent on an IV, but does not necessarily mean that a model is bad or should not be used. For example, CHW or HHW use plotted against OAT will usually show a "knee" in the data. Energy use on either side of the knee is typically modeled with separate linear regressions. The regression representing the "baseline" usage and having a flatter slope will usually show a very poor R^2, even if the actual energy use is visually very close to the regression line.

ASHRAE-14 gives no general acceptance criteria based on R^2 values. The IPMVP states that "though there is no universal standard for a minimum acceptable R^2 value, 0.75 is often considered a reasonable indicator of a good" correlation.

CV-RMSE: The coefficient of variation of the root mean square error (CV-RMSE) gives a sense for how accurate a model is, but not the degree of dependency of energy use on the IV. ASHRAE-14 gives acceptance criteria for the CV-RMSE of ≤20% for energy use and ≤30% for demand.

R^2 and CV_RMSE are standard outputs of all regression analyses. In UT3, they can be shown on the "Model Assembler" tab under both the "Baseline" and "Post Implementation" tabs in the M&V Module. In Excel, R^2 can be shown on a chart alongside the regression formula for a data set or calculated using the Regression analysis tool in the Data Analysis Tool Pack and the CV-RMSE can be calculated by dividing the Standard Error (in the Regression Statistics section of the output) by the average of the Predicted Y values (in the Residual Output section).

Options A and B – Retrofit Isolation

Options A or B can be used if energy savings are expected to be very small compared to whole-building energy use (<5%) and discrete measures are being implemented which can easily be calculated and supported by baseline and post-MBCx sub-metered or spot measured data. Measurement periods for these Options should attempt to follow the requirements detailed in the Option C section, however shorter trending periods may be warranted depending on the equipment and measures being modeled.

These approaches will likely only be used when EEMs which were scheduled for implementation have not been able to be implemented and the originally expected savings levels will not be reached. Approval must be given from the Partnership to utilize either of these approaches. Whole-building metering is still required if Options A or B are used.

Option D – Calibrated Simulation

Option D should be used only if either baseline or post-MBCx whole-building trend data is unavailable. Use of Option D entails creating a whole-building energy use model and calibrating it to either baseline or post-MBCx energy use. Depending on which data set the model is calibrated to, EEMs will then be implemented or un-implemented in the model to represent the actual project scope.

<u>Length of Trend Periods</u>

Whether trending occurs in the baseline or post-MBCx phase, the trending requirements detailed in the Option C section are to be followed. Additional sub-metering/trending will also be necessary to verify the assumptions used in the calibrated simulation which result in energy savings.

Energy Balance

If the simulation is truly a whole-building simulation, then an energy balance will be inherent in the model and the entire model will be compared to whole-building trend data for calibration. If the simulation only includes HVAC energy (or some portion thereof), then an energy balance needs to be performed to verify the portion of whole-building energy represented by the model. Typical EUI values for various end-uses in various building types can be found in the California End-Use Survey (CEUS) for use in an energy balance.

Calibration

If baseline trend data is available for an entire year prior to the MBCx project, the whole-building simulation should be calibrated to that annual use. (The trend data may need adjustments to make it more similar to a typical (TMY) year.) It is more often the case, however, that much less than a year's worth of either baseline or post-MBCx trend data is available. In that case, Option C-type energy models will need to be created in order to determine annual energy use to calibrate to.

ASHRAE Guideline 14-2002 references the Normalized Mean Bias Error (NMBE) and the CV-RMSE as the two metrics used for determining the degree of calibration of a whole-building calibrated simulation. (Reference sections 5.2.11.3 and 5.3.2.4,f of ASHRAE Guideline 14-2002.) Though calibrated simulation models will not be held to the acceptance criteria listed in ASHRAE, these metrics should be reported for all analyses.

Attachment 4 – Energy Models

There are several forms of regression model types used for Option C whole building M&V. The most well-known are simple linear regressions of monthly heating degree-days with monthly energy use. As more frequent measurements of energy use have become available, regression models have improved. The following is a summary of the most familiar types of regression modeling as well as available tools that help develop them:

Simple linear and multivariate linear regressions. These are well-known regression modeling methods, descriptions of which are in most statistics handbooks. Excel spreadsheets have regression functions, or a regression analysis tool pack that may be activated. Users can develop simple or multivariate regressions with whatever number and amount of independent variable data that are available, and manually develop and evaluate the goodness of fit and accuracy of models they develop.

ASHRAE Change-Point Models. ASHRAE's Research Project 1050 identified a series of change-point models that accurately modeled energy use with independent variables (usually ambient dry-bulb temperature) and validated them in over 400 buildings. The project also developed software to assist users in the development of change-point models for their building projects. The models are known by the number of parameters in the resulting change-point regression equation; a 2p model has two parameters and is a simple linear regression ($y = mx + b$); a 3p model describes a two-segment model, with one segment having a flat slope, a change-point, and another segment with a non-zero slope ($y = a + m(x - c)^+$, where c is the change point, and m is the value of the slope when x is greater than c, and y = a when x is less than c.). Change point models are recommended to be used with daily values of energy use, which may be sufficient for most projects. Software is available to run ASHRAE's change-point models; Energy Explorer from one of the original researchers is available from the University of Dayton.

Advanced Regression Models. When short time energy use and ambient temperature data is available for buildings that operate in a regular schedule, accurate regression models may be developed using an advanced regression algorithm that includes a time of week variable. The rationale is that the energy use at 10am on a weekday morning when ambient temperature is 65 degrees F may be much different than the energy use at 4pm when it is also 65 degrees F outside. *LBNL's temperature and time-of-week model (TTOW)* algorithm uses a time of week indicator variable and allows continuous or piecewise linear modeling of the independent variable, usually ambient temperature. The time-of week indicator variable applies a correction factor to the energy use predicted from the temperature. The model is represented by a matrix of coefficients, the dimensions of which depend on the analysis time interval (usually hourly or daily), and the number of line segments used for the temperature dependence. This regression algorithm has been tested on hundreds of commercial buildings and found to be very accurate.

The Universal Translator, version 3 (UT3). UT3 is a free tool downloadable from http://utonline.org/cms/ after an account is created. It has many features that help users manage large sets of data, including merging files, re-sampling time intervals, filtering, charting, calculating, importing and exporting. The tool was designed so that anyone with the software could share data and analysis with anyone else who had the tool, such as project reviewers. This increases project transparency. There are many tutorial videos provided on the website.

The website provides a system development kit that allows UT3 users to develop their own analysis modules. The California Energy Commission's PIER program sponsored the development of several analysis modules, one of which is the M&V analysis module. Referred to as the M&V Tool, this M&V

analysis module allows users to develop LBNL's TTOW model, or simpler temperature-only and time-only models. Users may use filters to set up analysis bins of occupied or unoccupied periods, and the M&V Tool allows different models to be developed for each of these periods and pieced together. It provides the R^2 and CV(RMSE) metrics for each model development run so that users may evaluate the model's goodness of fit and accuracy. The M&V Tool calculates savings for actual projects by adjusting the baseline energy use to post-installation conditions. It also allows users to calculate savings under normalized conditions, such as those defined by TMY3 weather data sets. This feature also allows users to estimate annual energy use and savings based on a shorter period of measured data, such as three months. A tutorial video on the use of the M&V Tool is also available on the website.

Other Analysis Tools: Other regression analysis tools can be used but should be able to perform an energy savings analysis based on short-time interval energy use data and independent variable data (such as outside air temperature). Many IPMVP Option C projects use multi-variate regression models to predict baseline and post installation energy consumption. As the name infers, multi-variate regression models use multiple independent variables. Unlike the UT3, multi-variate regression models can use many independent variables not related to time, such as outside air temperature, outside air wet-bulb temperature, building cooling load, etc. The multi-variate regression models may also use time based logical independent variables like holidays, weekdays, classes in session, night time, etc. A properly constructed multi-variate regression model can be more sophisticated and accurate. The tool should indicate the quality of the model by displaying its R2 and CV-RMSE values. The tool should create annual energy savings estimates by applying the pre and post implementation models to TMY3 weather data.

Refer to Attachment 3 for details on reasonable R^2 and CV-RMSE ranges for regression models.

Attachment 5 - General Types of Building Systems to be Investigated

Central Plant(s) including the following general types of equipment:

- Chillers
- Cooling Towers
- Boilers
- Pumps
- Control Systems including VFDs and sequences of control
- Waterside Economizers

Central Air Handler(s)

- Fans
- Chilled water coils and valves
- Hot water coils and valves
- Dampers
- Control Systems, including VFDs, Outside Air Economizer and other sequences of control

Zonal HVAC

- Depending upon the number of zones, zonal equipment may initially be evaluated by Provider by sampling, and the extent of problems will determine whether all zones need to be evaluated and whether any discovered problems are assumed to be global, and that solutions may be applied globally ("Global" as used here means similar units serving similar types of zones)
- HVAC delivery to the Space (air and/or water distribution, whether dual duct, VAV terminals with re-heat, hydronic, etc.)
- Control Systems and sequences of control for HVAC delivery and zonal temperature control

Major Unitary Systems

- Rooftop Package Units (15 Tons or over)
- Controls

Lighting Systems

- Interior Lighting Controls
- Exterior Lighting Controls

Refrigeration Systems

- Controls

Domestic Hot Water Systems

- Heaters/Boilers
- Controls

Process Controls

Attachment 6 - Typical MBCx Measures

A wide range of energy efficiency measures may be implemented under the Program. Most commonly, energy efficiency measures will apply to the following system components: air handlers, chillers, cooling towers, economizers, boilers, lighting, and controls. While measures will be determined on a site-by-site basis, the Program's common MBCx measures include:

- Scheduled Loads
  - Equipment Scheduling: Time of Day
  - Equipment Scheduling: Optimum Start-Stop
  - Equipment Scheduling: Lighting Controls
- Economizer/Outside Air Loads
  - Economizer Operation: Inadequate Free Cooling
  - Over-Ventilation
  - Demand Controlled Ventilation
- Control Problems
  - Simultaneous Heating and Cooling
  - Sensor/Thermostat Calibration and/or Optimal Relocation
  - Hunting and Loop Tuning
  - Damper/Valve Actuator Calibration
  - Zone Rebalancing
- Controls: Setpoint Changes
  - Duct Static Pressure Setpoint
  - Piping Differential Pressure Setpoint
  - Reduction of VAV Box Minimum Setpoint
  - Implementation/Adjustment of Heating/Cooling, and Occupied/Unoccupied Space Temperature Setpoints
- Controls: Reset Schedules
  - HW Supply Temperature Reset or HW Plant Scheduling
  - CHW Supply Temperature Reset
  - CW Supply Reset for Chiller Efficiency Optimization (for Newer VFD Chillers)
  - Supply Air Temperature Reset: Cooling and Heating
  - Duct Static Pressure Reset
- Equipment Efficiency Improvements / Load Reduction
  - De-Lamping of Over-Lit Spaces
  - Pump Discharge Throttled, Over-Pumping and Low Delta T–Trim Impeller
- Variable Frequency Drives (VFDs)
  - VFD Retrofit - Fans
  - VFD Retrofit - Pumps
- Equipment Maintenance
  - Leaking Valves (hot water or chilled water valves)
  - Actuator / Damper Operation

The goal of the MBCx program is to implement the following types of measures:

- Fix problems with existing controls
- Enhance the control and operation of existing equipment
- Make repairs/upgrades to existing equipment to make it run more efficiently

- All energy saving projects are allowed, provided they do not include installation of large pieces of equipment, such as a new chiller, boiler or air handler.

Recommendations to improve the facility performance, such as indoor air quality issues, should be noted in the MBCx Baseline Report, even if there are no energy savings associated with them. Minimum ventilation requirements must be maintained per code.

Attachment 7 – DEER (Database for Energy Efficient Resources) Demand Definition

Table 5. CPUC Defined DEER Peak Periods by Climate Zone
(Beginning July 1, 2014)

Climate Zone	Start Date	End Date
1	16-Sep	18-Sep
2	8-Jul	10-Jul
3	8-Jul	10-Jul
4	1-Sep	3-Sep
5	8-Sep	3-Sep
6	1-Sep	3-Sep
7	1-Sep	3-Sep
8	1-Sep	3-Sep
9	1-Sep	3-Sep
10	1-Sep	3-Sep
11	8-Jul	10-Jul
12	8-Jul	10-Jul
13	8-Jul	10-Jul
14	26-Aug	28-Aug
15	25-Aug	27-Aug
16	8-Jul	10-Jul

The periods are based on a typical year using a 1991 calendar for projects submitted before July 1, 2014 and a 2013 calendar for projects submitted on or after July 1, 2014. DEER interactive

Source: IOU Statewide Customized Offering Manual, Section 2: Customized Calculated Savings Guidelines

DEER Peak Demand Reduction Calculations

DEER Peak reduction estimates depend on the measure type, measure operation, and level of data available. The DEER Peak method is the average grid level impact for a measure between 2:00 p.m. and 5:00 p.m. during the three consecutive weekday periods containing the weekday temperature with the hottest temperature of the year.

The DEER Peak periods are defined by individual climate zones. Because the definition is based on average grid-level impacts it has been determined that all measures must use the predefined periods.

Source: IOU Statewide Customized Offering Manual, Section 2: Customized Calculated Savings Guidelines

Follow link below for a description of California Climate Zones

http://www.energy.ca.gov/maps/renewable/building_climate_zones.html

Attachment 8 – Sample MBCx Report Components

1. **MBCx Baseline Report**
    1.1. Introduction
        Include summary of all projected costs, savings, and incentives.
        Campus benchmark ranking and bar chart of actual data compared to other campuses; building benchmark data if available
    1.2. Facility Description
        Area, age, function, schedule, contacts, operational requirements (schedules, occupancy, etc.)
        Available and missing documentation identified
    1.3. Scope of Services
        Basic MBCx scope and systems being evaluated
        Description of existing controls and trending capacities
        Description of new monitoring capabilities and/or control points to be added
    1.4. Known issues, improvement opportunities, and potential MBCx measures identified at this stage.
        Include projected costs and savings, anticipated incentive.
        Summary Table of Proposed Measures, including projected savings, costs, expected incentives
        Discussion of Analysis of the Potential MBCx Measures and Savings Projections
    1.5. Historical Energy Use
        Annual Energy Use and Costs to Campus
    1.6. MBCx Plan / Measurement and Verification Plan
        1.6.1. Monitoring objectives and requirements
        1.6.2. Identify measurement points and planned duration of data collection
        1.6.3. MBCx Process
        1.6.4. Roles and Responsibilities
        1.6.5. Project Schedule
        1.6.6. Pre-Functional Test Plan
        1.6.7. Functional Test Plan
        1.6.8. Operator Training Plan
        1.6.9. (Optional Section) Other, non-whole-building M&V methods to be utilized
        1.6.10. Plans for M&V Data Analysis (e.g., extrapolation, normalization, adjustment)
    1.7. Baseline Report
        1.7.1. Baseline system/equipment meter data gathering plan and data summary for each measure. Include the revenue meter numbers that savings will accrue to.
        1.7.2. Discussion of baseline system/equipment data analysis
        1.7.3. Assessment and proposed solutions
        1.7.4. Assessment and analysis of whole-building metering data, if not included in 1.7.2.

        Appendices
            MBCx Kickoff Meeting Minutes
            Initial Project Deficiency and Resolution Log
                Name of System or Equipment
                Description of Finding, Deficiency or Problem
                Date Noted
                Recommended Solution
                Estimated Cost of Correction
                Status of Implementation
                Actual Cost of Correction

Verification of Implementation
Conclusion Date
Baseline Data and Analysis files on CD or similar format

2. MBCx Final Report

2.1. Executive Summary
2.2. MBCx Findings/Initiation Report, including baseline analysis (updated if required)
2.3. As-installed report
   2.3.1. Installed energy conservation measures: describe in detail including sequence modifications
   2.3.2. Discussion of corrected baseline (if necessary)
   2.3.3. As-installed system/equipment metering data gathering plan and data summary
   2.3.4. Discussion of energy savings calculations for each measure or package of measures & savings table
   2.3.5. Provide actual field data that savings are based upon (include whole building interval data when available)
   2.3.6. ECM persistence recommendations
2.4. Discussion of operator training activities
2.5. Discussion of final findings log
2.6. Additional goals and recommendations
2.7. Remaining improvement opportunities
2.8. List any retrofit project identified as a result of the MBCx process

Appendices
Initial Project Deficiency and Resolution Log (from time of Baseline Measurements)
Final Project Deficiency and Resolution Log
Pre- and Post-Implementation Trend Data and Energy Savings Calculations
(Include actual data and post-processed files on CD, DVD, or FTP)
All MBCx Team Meeting Minutes
Training Session Attendance Records and Materials

3. MBCx Systems Manual

3.1. MBCx Final Report
3.2. Alarm set points
3.3. Available monitoring points and active trending capabilities
3.4. Control graphics or diagrams
3.5. O&M plan
3.6. Ongoing diagnostics
3.7. M&V Plan
   3.7.1. General building or plant info & Design intent (current facility requirements)
   3.7.2. System diagram and descriptions
   3.7.3. Equipment schedules & control sequences (this includes setpoints)
   3.7.4. Available monitoring points and recommended trend groups
   3.7.5. ECM persistence recommendations
   3.7.6. Updated findings log and action plan
   3.7.7. Updated benchmarking and baseline data

3.7.8. Operator training plans and records
3.7.9. Plans for Recommissioning to maintain persistence (15 years).
3.7.10. Summary of available as-built records & documentation

Attachment 9 – MBCx Measure Log

The MBCx Measure Log should be used to record each measure that is implemented as part of the MBCx project and should be included with the final MBCx report.

The following is an example of what an MBCx Measure Log should consist of:

	EEM Description	**Equipment**	**Implementation Date**
1	Ex: Implement a duct static pressure reset strategy	AHU-1, AHU-3	2/18/2015
2			
3			
4			
5			
6			
7			
8			
9			
10			

Attachment 10 – Building Operations Log

The Building Operations Log should be maintained for the life of the MBCx project, starting the same date the baseline trending period begins, and continuing for the following five years after the completion of the project. The log should include any major changes to the building's operation, including: major scheduling changes, major equipment replacements, building remodels or additions, retrofit projects, etc.

The purpose of the log is to document any major changes to the building that may have an effect on the energy savings associated with the MBCx project. This log should be maintained by the campus and kept on file for up to a period of five years after the MBCx project has been completed. A copy of the log maybe request by the Energy Division as part of secondary project review during that time period.

The following is an example of what a Building Operations Log should consist of:

	Description of Change	**Date of Change**
1	Ex: The buildings operating schedule was changed from Mon. through Fri. 8am - 8pm to Mon. through Sat. 8am - 9pm.	2/18/2015
2		
3		
4		
5		
6		
7		
8		
9		
10		

Attachment 11 – Baseline Documentation Approval Form Details

Approval from the Partnership to proceed to the MBCx measure implementation phase is required. Along with the Baseline Documentation Approval Form, the campus or Cx agent must submit a baseline MBCx report, energy savings calculations, and the raw trend data used for the calculations, as outlined in the "Baseline Report" section above, for review by the Partnership. Once the submitted report and calculations are approved, the Partnership will issue a signed Baseline Documentation Approval Form the campus or Cx agent as notice to proceed with implementation.

The form will be provided to the campus or Cx agent by the Partnership.