MBCx Project Requirements

Monitoring Based Commissioning (MBCx) Program
2009-2011 Higher Education / Investor Owned Utility Partnership Programs

April 2009

<u>Monitoring Based Commissioning</u>

The Higher Education / IOU programs support MBCx for individual buildings or multiple buildings at UC, CSU and CCC campuses. MBCx is a unique combination of building monitoring and commissioning. The monitoring supports the commissioning effort by providing a diagnostic tool, as well as by documenting energy savings in the near term and increasing the persistence of those savings over the long term.

The MBCx process includes the following steps:

- Use a benchmarking process to select the best candidate buildings for MBCx.
- Apply to the Partnership for project approval.
- Install whole building meters to accurately establish the baseline energy use of the buildings.
- Perform functional testing to identify basic operating problems.
- Log the energy use and key EMS points in a database per program guidelines.
- Utilize physical investigation, control sequence review and database analysis to identify and evaluate opportunities to improve the energy efficiency of the building.
- Document potential operational and capital modifications to reduce electricity and gas use.
- Implement low and no cost modifications.
- Measure actual energy savings per program guidelines and project annual savings.
- Document the process in a report and receive Partnership incentive.
- Perform ongoing monitoring to ensure the persistence of the savings in future years.
- Implement the capital modifications through future funding.

This work can be done by the campus in house, or portions of it can be contracted to an MBCx agent. If an MBCx agent is used, training of campus personnel must be included in the work.

This Minimum Program Requirements document describes the basic steps necessary for the implementation of these projects.

<u>Campus Eligibility</u>

The campus should take either electricity or natural gas service from an Investor Owned Utility to qualify for the Higher Education / IOU MBCx Program. The campus may buy commodity electricity or gas from a supplier other than the IOU. The campus can house a cogeneration plant if it does not sell excess power to the utility, or a PV or other renewable plant that is net metered.

<u>Commitment</u>

The campus must commit to implement all recommended no and low cost measures from the MBCx evaluation that it agrees are feasible.

The campus must measure pre and post implementation energy use to provide solid documentation of annual energy savings. The Program incentive will be based on this measured savings.

Application

The campus submits the program application showing building area, building function, and current baseline metered or estimated energy use. This includes electricity and natural gas entering the building, as well as steam, hot water and chilled water delivered to the building from a central plant. Additional metering may be necessary if there are other energy flows, such as chilled water supply to other facilities.

The campus should select buildings with high energy use intensity relative to other buildings on campus, or relative to other buildings which serve similar functions. Select buildings which meet other program requirements, such as no demolition or significant reconstruction planned for the next 10 years, basic HVAC and lighting equipment is in operational condition, no other energy projects are currently being implemented, and the building air handlers and plant are controlled by direct digital controls.

The campus should provide a realistic schedule breakdown for implementation of the project.

Metering

Implement an M&V plan to install whole building metering to measure all electric, gas, steam, hot water and chilled water inputs to the building. Use existing meters as available, with new pulse outputs if necessary. The meters should automatically communicate interval energy use (using hourly or smaller intervals) to a front end storage device in real time. Install submeters as necessary to break out particular equipment energy use. Calibrate all new and existing meters. Small energy flows, such as Bunsen burner gas, do not need to be measured.

Define the necessary periods of time to collect adjusted baseline and post implementation energy use to allow accurate projection of annual building energy use for the adjusted baseline and for the post implementation energy use. Refer to the 2009-2011 Higher Education / IOU Partnership MBCx Measurement Protocol Guidance document of March 2009 for specific requirements.

For MBCx projects at central plants, the whole building metering requirement includes energy streams entering and leaving the plant so that overall efficiency can be evaluated.

Database Program

Implement a database program specifically designed for the tracking and evaluation of energy use meters and EMS points. The program should have the ultimate capability to log, store and manipulate energy use information for every major building on campus for at least 10 years. These capabilities are beyond the capacity of many energy management systems.

The system should have the ability to communicate with existing campus energy management systems to allow logging of points or virtual points from the EMS for use in the database program. The program will allow multiple ways to view and display data, including with data visualization software.

Evaluation

Perform functional testing for the major mechanical equipment in the building. Identify deficiencies in operations and correct deficiencies to bring building up to a minimal operating point. Utilize the findings from the functional testing and evaluations of the energy use load profile and EMS point logs as the basis for identifying ways to improve the efficiency of the building. Project cost and savings for recommended measures. A report of findings is presented to the campus for its approval.

Implementation

The campus implements the low and no cost measures evaluated in the report.

Reporting

Follow the M&V plan to create the post implementation energy use. Subtract the post implementation energy use from the Adjusted Baseline to calculate annual energy savings.

Report these results in the program spreadsheet to document energy savings, including a comparison of savings with original program commitments.
.

Documentation

Document the MBCx process through the reporting procedures outlined in the enclosed MBCx Report Components.

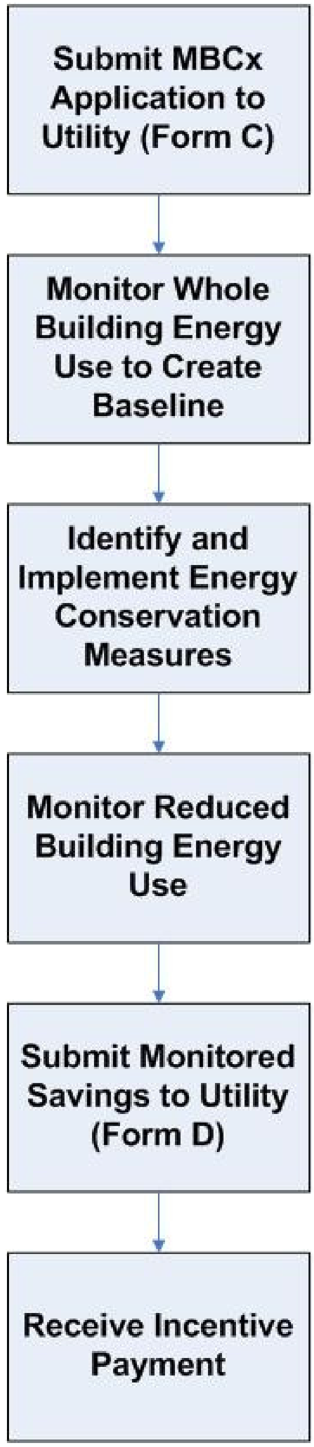
Ongoing

Program the database to evaluate data collected in the following years to alarm operators when energy use patterns or other indicators show that operations have changed or that energy use is drifting up.

Training

Train campus operators in the revised sequences of operation and monitoring systems.

Basic MBCx Process



*Note: To receive incentive, project must pass due diligence and a Project Agreement must be signed

List of Attachments

Attachment 1
Recommended MBCx Process Schedule

Item	Suggested Timeframe/Duration	Deliverable	
		Report	Partnership Form
Planning Phase			
Use a benchmarking process to select the best candidate buildings for MBCx (optional for CSU and CCC, but recommended)	Prior to application for MBCx Incentive		Form C.1 (optional)
Submit Form C-MBCx Project Application for best candidate buildings			Form C
Project approval from Partnership Management Team			
Investigation and Implementation Phase			
Provider performs initial site investigations			
Install whole building meters to accurately establish the baseline energy use of the building(s). Log energy use and key EMS parameters in a database. Ensure that meters and sensors are calibrated correctly. See Attachment 5 for detailed requirements for baseline measurements.	Baseline data should be collected for up to 3 months. Prior collected trending data can be used if available.		
Perform pre-functional testing to identify basic operating problems. Analyze energy and EMS database to identify operational and capital modifications to reduce electricity and gas use, and electricity demand.	Prior to generation of MBCx Baseline/Findings Report		
Campus Delivers MBCx Baseline/Findings Report to IOU. See Attachment 2 for report components.	Approximately 4 months from Partnership approval (IOU to provide comment, but approval not required to proceed)	Report	
Campus emails list of measures from MBCx Initiation/Findings Report that will be implemented to IOU	One week from delivery of MBCx Baseline/Findings Report	email	
Implementation of selected measures	Measure implementation period can last up to 3 months		
Post-functional testing of modified systems			
Document remaining improvement opportunities			
Measure post-implementation energy use. Normalize data and extrapolate to show annual energy savings achieved. See Attachment 5 for detailed requirements for post-implementation measurements.	Post-implementation data should be collected for up to 3 months.		

Item	Suggested Timeframe/Duration	Deliverable	
		Report	**Partnership Form**
Closeout Phase			
Campus delivers Draft MBCx Final Report and to IOU See Attachment 2 for outline.	Approximately 10 months from IOU acceptance of Form C. IOU to review and comment.	Report	
Campus delivers Final MBCx Final Report to IOU		Report	
Provider conducts MBCx Training for Campus (records of Training Sessions to be included in MBCx Systems Manual).			
Provider delivers MBCx Systems Manual to Campus. Campus notifies IOU of receipt of Manual. See Attachment 2 for outline		Report	
Campus submits Form D-MBCx Summary Report to IOU	IOU to Review and Approve		Form D
Campus receives MBCx Incentive Payment	Approximately 11 months from IOU Acceptance of Form C		

Attachment 2
MBCx Report Components

1. **MBCx Baseline/Findings 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 3
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

Attachment 4
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 5
Typical 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 (VFD)
  - 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 limited repairs/upgrades to existing equipment to make it run more efficiently.

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

Attachment 6
Measurement Protocol Guidelines

MBCx (Monitoring Based Commissioning)
2009-2011 Higher Education/ IOU Partnership

MBCx projects should quantify energy savings through procedures in accordance with IPMVP. The preferred IPMVP approach is the Option C – Whole Building[1] method, although other Options can be used with justification. The use of alternative IMPVP Options does not eliminate the need for whole building metering of all utilities.

The following specific accommodations are required for the use of Option C in the Partnership program:

- Typical Savings: Expected building energy savings should typically be more than 5% of the base-year energy use.

- Independent Variables: In order to establish and adjust baseline energy use, the following variables should be tracked at a minimum:

    - Outside Air temperatures - hourly or daily average data
    - Building operating hours (e.g., weekday hours and weekend hours for both in-session and out-of-session periods)
    - Occupancy – whether the university is in-session or out-of-session (separate regression models may need to be developed for these periods)

  Additionally, data for potential special adjustments should also be captured, including:

    - Major changes in building plug loads (e.g., a computer monitor upgrade project)
    - Any batch processing occurring and associated hours

- Measurement Period:

Minimum Measurement Period to Establish Baseline

	Buildings without pre-existing metering (metering capability to be installed with MBCx project).	**Buildings with pre-existing metering or building level monthly records of all main energy uses (metering capability to be upgraded with MBCx project).**	**Buildings with pre-existing metering and full trending capability.**
kWh, kW	Three consecutive months of whole building interval electric data (and CHW if served by plant not on bldg meter) not including January or July. Annualized using independent variables above.	Four weeks of whole building interval electric data (and CHW if served by plant not on bldg meter), including at least two weeks at full occupancy. Annualized by reconciling with one year historical usage data.	Baseline may be established with at least three consecutive months excluding January and July of existing data from pre-existing energy information system. Annualized using above independent variables if necessary.

[1] International Performance Measurement and Verification Protocol (IPMVP). See Volume I "Concepts and Options for Determining Energy and Water Savings"

Gas, Hot Water, Steam	Three consecutive months of whole building interval gas, (and HW and steam if served by plant not on bldg meter) not including January or July. Annualized using independent variables above.	Four weeks of whole building interval gas, (and HW and steam if served by plant not on bldg meter) from either fall or spring season, including at least two weeks at full occupancy. Annualized by reconciling with one year historical usage data.	Baseline may be established with at least three consecutive months excluding January and July of existing data from pre-existing energy information system. Annualized using above independent variables if necessary.

After MBCx measure implementation, the savings reporting period should be at least three months as in the first column above, and ideally in the season opposite the baseline (i.e., if baseline established in the spring, post-implementation measurement period in the fall).

Attachment 7
Definitions

1) Monitoring Based Commissioning (MBCx): A systematic process for optimizing an existing building's performance by identifying operational deficiencies and making necessary adjustments to correct the system. Emphasis on whole building metering, data base analysis and storage of energy records, long term monitoring of projects.

2) Campus: Applicant for the Higher Education / IOU Monitoring Based Commissioning Program

3) MBCx Provider: Consultant hired by the campus to perform Monitoring Based Commissioning Services

4) IPMVP: International Performance Measurement and Verification Protocol

5) Pre-functional Test: Test that evaluates the dynamic function and operation of equipment and systems using manual or automated monitoring methods and either passive observation or active testing of operation.

6) Functional Test: The assessment of the system's ability to perform within the parameters described in the design.

7) Peak Demand: the average grid level impact for a measure between 2 p.m. and 5 p.m. during the three consecutive weekday periods containing the weekday with the hottest temperature of the year. Refer to DEER Peak Demand definition, Attachment 7.

Attachment 8
DEER Demand Definition

DEER
Peak Demand Definition

DEER Demand Definition
Adobe Acrobat Document

CA Climate Zones
Adobe Acrobat Document

Max Demand (DEER): For weather dependent measures, the peak demand definition used in the 2005 Database for Energy Efficiency Resources (DEER) update is as follows:

- Average demand reduction over a nine hour period for the installed measure
- 2 pm - 5 pm
- 3 consecutive weekday period containing the highest temperature of the year.

The dates and associated weather bin data from TMY weather data are summarized below for use in calculations. If using eQUEST or other DOE2 software, these defniitions may already be incorporated. For additional explanation, the full details can be found in the attached pdf document. Note that a different set of maximum temperature hours can be used for educational facilities.

The following are the wet and dry bulb temperatures for the Maximum Demand hours in the eQUEST weather files. The average wet and dry bulb temperature for these nine hours is calculated for each Climate Zone.

CZ01

	30-Sep		1-Oct		2-Oct		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	61	67	62	74	57	60		
16	62	69	61	71	55	56	59	**65**
17	61	67	59	66	56	56		

CZ02

	22-Jul		23-Jul		24-Jul		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	65	98	69	99	65	92		
16	64	95	69	97	65	91	66	**94**
17	63	93	69	94	64	83		

CZ03

	17-Jul		18-Jul		19-Jul		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	67	80	67	84	68	78		
16	66	79	66	82	68	78	66	**79**
17	64	75	64	79	65	74		

CZ04

	17-Jul		18-Jul		19-Jul		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	73	87	73	94	75	86		
16	74	86	73	90	75	86	73	**87**
17	72	83	71	86	75	82		

CZ05

	3-Sep		4-Sep		5-Sep		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	65	84	58	84	60	77		
16	63	82	55	82	59	71	59	**79**
17	62	81	55	80	58	71		

CZ06

	24-Sep		25-Sep		26-Sep		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	68	79	63	71	60	67		
16	68	81	64	70	61	67	64	**72**
17	68	79	63	67	60	64		

CZ09

	23-Sep		24-Sep		25-Sep		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	69	96	74	102	66	86		
16	68	96	74	100	64	82	69	**92**
17	69	94	73	94	62	77		

CZ10

	12-Aug		13-Aug		14-Aug		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	66	98	67	104	71	101		
16	68	99	67	103	70	96	68	**99**
17	68	95	67	99	69	93		

CZ11

	21-Aug		22-Aug		23-Aug		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	64	96	65	99	67	100		
16	64	97	65	99	67	101	65	**98**
17	64	94	64	95	66	97		

CZ12

	22-Jul		23-Jul		24-Jul		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	64	90	67	99	74	102		
16	64	92	67	101	72	103	68	**98**
17	64	92	69	101	72	100		

CZ13

	30-Jul		31-Jul		1-Aug		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	63	98	67	101	74	105		
16	65	98	69	101	72	106	68	**101**
17	63	96	67	99	71	104		

CZ14

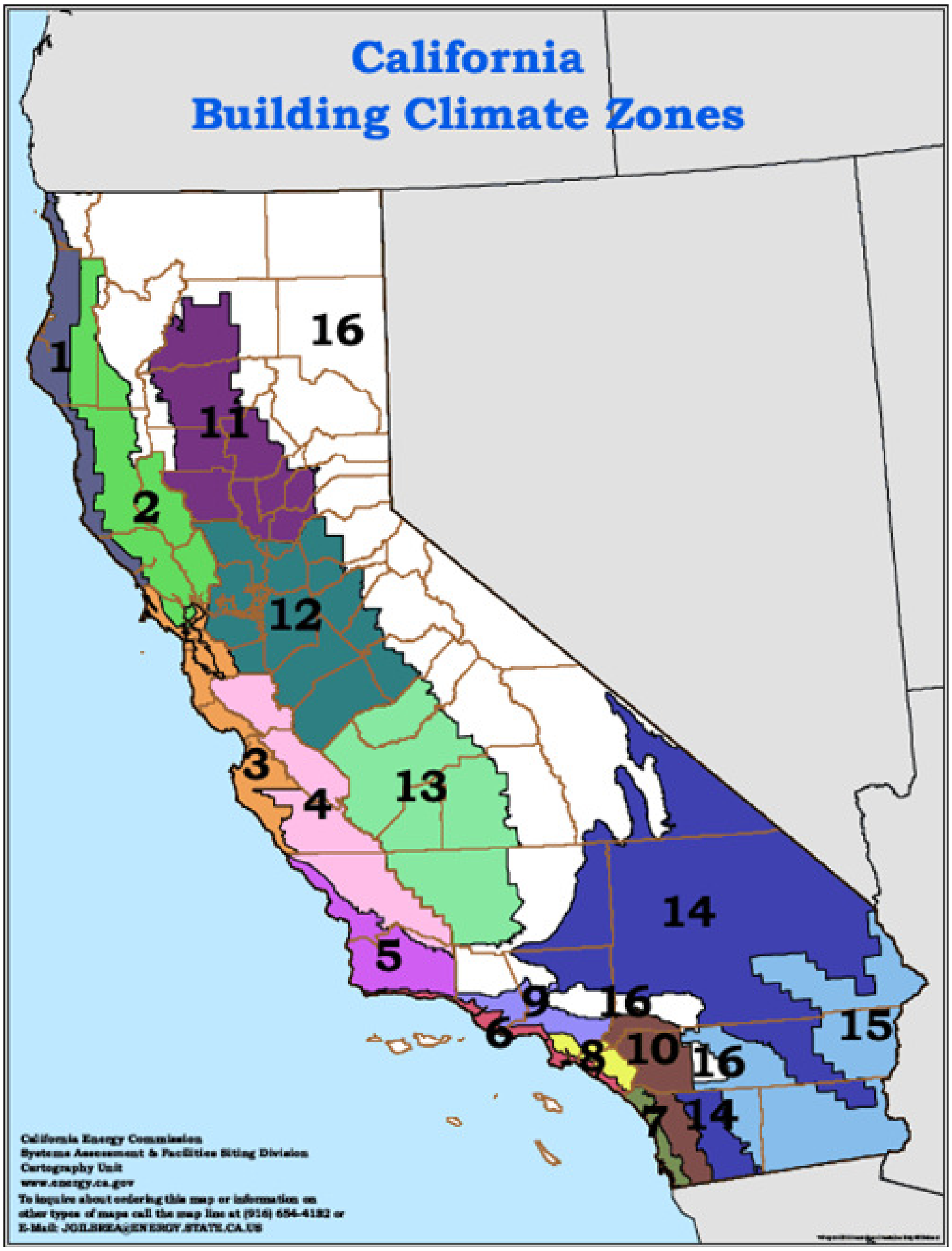
	15-Jul		16-Jul		17-Jul		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	61	103	62	102	63	102		
16	62	104	61	102	63	102	62	**103**
17	61	103	62	102	63	103		

CZ07								
	9-Sep		10-Sep		11-Sep		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	72	81	69	80	64	84		
16	70	78	70	82	58	70	67	**78**
17	71	78	69	79	58	67		

CZ15								
	9-Sep		10-Sep		11-Sep		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	67	108	65	108	67	111		
16	66	106	66	108	66	110	66	**107**
17	66	105	65	104	64	107		

CZ08								
	23-Sep		24-Sep		25-Sep		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	61	90	63	93	62	92		
16	58	84	62	92	63	90	61	**89**
17	58	83	62	88	62	87		

CZ16								
	26-Aug		27-Aug		28-Aug		Averages	
Hour	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)	WB (°F)	DB (°F)
15	61	90	60	91	63	85		
16	61	91	60	91	63	84	61	**87**
17	59	85	58	84	61	81		



Attachment 9
Selection Guidelines for Metering, Communications, and Data Storage

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 either if the following locations:

> http://www1.eere.energy.gov/femp/operations_maintenance/om_resources.html
> http://www1.eere.energy.gov/femp/pdfs/mbpg.pdf (direct link)

Below are some relevant excerpted highlights from the FEMP document.

Electricity Metering

Advanced (solid state/digital) electric meters are shown to be an acceptable choice for MBCx purposes on page 5.8.

> ***Advanced (solid state/digital) Electric Meters***: Different from mechanical/electro-mechanical meters, advanced meters require no moving parts, rather they rely on sophisticated integrated circuits with current and voltage transformers, on-board memory, and communication technology.
>
> Advanced meters are those that have the capability to measure and record interval data (at least hourly for electricity) and communicate the data to a remote location in a format that can be easily integrated into an advanced metering system. These meters measure electrical demand (kW) over a predetermined interval—commonly every 15 minutes to match utility billing intervals. Other intervals (e.g., 1 minute, 5 minute, hourly) can be accessed and are useful for examining equipment performance, trending, and start/stop characteristics. With availability and versatility of advanced meters increasing and capital costs falling, these meters are quickly gaining market share and acceptance.
>
> Advanced meters can take a variety of shapes and sizes (also known as the meter "form factor"), from the familiar circular socket-based style to an array of rack and panel-mount configurations. Depending on the manufacturer and model, advanced meters have accuracies in the range of 0.2 to 3.0 percent, with most in the 0.2 to 0.5 percent range. Equipment costs for these meters can also vary by manufacturer and features selected; typical advanced meter cost range from $1,000 to $3,000.
>
> Properly configured, advanced meters meet EPAct (hourly interval data with daily downloads) and most models go well beyond with advanced features. Some of the more common features of advanced meters are listed below:
>
> - Data storage and time-stamp capabilities – meters can record and store energy, demand, and diagnostics in a time-series record with user selectable intervals.
>
> - Multiple modes of communication – most meters have capabilities from traditional phone modem to networked connections and wireless options. In addition, some meters allow for multiple communication options and include an ability to be a communications hub for other devices such as gas or water metering devices.

Natural Gas Metering

Selection criteria for natural gas meters are laid out in Table 5.1 on page 5.22.

Table 5.1. Common Natural Gas Metering Technologies and Key Criteria

Criteria	Positive Displacement	Orifice	Venturi	Annubar	Turbine	Vortex Shedding
Accuracy	Good	Moderate	Good	Good	Good	Good
Turndown Ratio	10:1	<5:1	<5:1	10:1	10:1	20:1
Repeatability	Good	Good	Good	Very Good	Low	Very Good
Installation Ease	Easy	Easy	Moderate	Easy	Challenging	Moderate
Pressure loss	Medium	Moderate	Low	Low	Moderate	Low
Recalibration Needs	Infrequent	Frequent	Infrequent	Infrequent	Frequent	Infrequent
Capital Cost	Low	Low	Moderate	Low	Moderate	Moderate
Installed Cost	Moderate	Low	Moderate	Low	Moderate	Moderate
Maintenance Cost	Low	High	Moderate	Low	Moderate	Low

Steam Metering

Selection criteria for natural steam meters are laid out in Table 5.2 on page 5.30.

Table 5.2. Common Steam Metering Technologies and Key Criteria

Criteria	Orifice	Annubar	Turbine	Vortex Shedding
Accuracy	Moderate	Good	Good	Good
Turndown Ratio	<5:1	5:1	10:1	20:1
Repeatability	Good	Good	Low	Very Good
Installation Ease	Easy	Easy	Challenging	Moderate
Pressure loss	Moderate	Low	Moderate	Low
Recalibration Needs	Frequent	Infrequent	Frequent	Infrequent
Capital Cost	Low	Low	Moderate	Moderate
Installed Cost	Low	Low	Moderate	Moderate
Maintenance Cost	High	Low	Moderate	Low

Hot Water and Chilled Water Metering

Selection criteria for hot water and chilled water meters are laid out in Table 5.4 on page 5.50.

Table 5.4. Common Water Metering Technologies and Key Criteria

Criteria	Positive Displacement	Orifice	Venturi	Turbine	Vortex Shedding	Ultrasonic Dop/TT
Accuracy	Good	Moderate	Good	Good	Good	Moderate
Turndown Ratio	10:1	<5:1	<5:1	10:1	20:1	10:1 / 20:1
Repeatability	Good	Good	Good	Low	Very Good	Good
Installation Ease	Easy	Easy	Moderate	Challenging	Moderate	Very Easy
Pressure loss	Medium	Moderate	Low	Moderate	Low	None
Recalibration Needs	Infrequent	Frequent	Infrequent	Frequent	Infrequent	Moderate
Capital Cost	Low	Low	Moderate	Moderate	Moderate	High
Installed Cost	Moderate	Low	Moderate	Moderate	Moderate	Low
Maintenance Cost	Low	High	Moderate	Moderate	Low	Low