Monitoring-Based Commissioning (MBCx) Plan Template

Hannah Kramer
Eliot Crowe
Jessica Granderson

Building Technology and Urban Systems Division

Lawrence Berkeley National Laboratory

Prepared for Amy Jiron

DOE Building Technologies Office

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Purpose

The intent of the Monitoring-Based Commissioning Plan Template is to assist building staff in developing a monitoring-based commissioning (MBCx) process. MBCx is a process which maintains and continuously improves building performance over time. MBCx is defined as the implementation of an ongoing commissioning process with focus on monitoring and analyzing large amounts of data on a continuous basis.

This template guides development of an MBCx Plan that uses Energy Management and Information Systems (EMIS) for ongoing monitoring and analytics. EMIS comprise a broad family of tools that may also be paired with technical services to manage commercial building energy use. These technologies offer a mix of capabilities to store, analyze, and display energy use and system data, and in some cases, provide control.

This MBCx Plan can be used by organizations wishing to implement meter analytics with an energy information system (EIS), and/or heating, ventilation and air conditioning (HVAC) operational fault detection and diagnostics (FDD). MBCx may utilize either a new or previously installed EIS/FDD system.

Assumptions

This template is not intended to be used as an MBCx guideline or standard; it is assumed that the user of this template is already familiar with the MBCx process. The 3rd edition of the *Building Commissioning Handbook* includes a chapter with detailed guidance on the MBCx process. It is also assumed that the user of this template already has selected a building or buildings for MBCx and has a provisional team in place for implementing the program.

How to Use this Template

The template is designed for use by building staff (e.g., an Energy Manager) or a third party (e.g., Commissioning Provider). Once created, the MBCx Plan drives a thorough, methodical MBCx process and helps ensure that all team members (internal and external) are fully aware of the plan and their responsibilities. The template offers introductory language under each section heading and additional supporting reference material in the appendices. The structure of this template is built around best practice concepts and can be tailored to the unique needs and scope of each MBCx program. The template includes two types of highlighted text:

- [Gray highlighted text is instructional, and may be deleted.]
- [Yellow highlighted text is example content, which may be edited or deleted per your organizational needs.]

Monitoring-Based Commissioning Plan

[Organization Name]

[Building or Portfolio]

Submitted by

[Company Name and Address]

[Date]

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Glossary

Automated System Optimization (ASO) Software: Automated System Optimization software is a subset of EMIS focused on continuous controls optimization. ASO tools dynamically modify building automation system control settings to optimize HVAC system energy usage while maintaining occupant comfort. Two-way communication with the BAS is a distinguishing feature of ASO.

Baseline: A representation of "standard" or typical energy performance, used for comparative purposes. The baseline may be expressed according to a variety of metrics and may account for weather or other independent variables that influence energy consumption.

Benchmarking: Comparing building energy performance to that of similar buildings (cross-sectional benchmarking) or its own historic performance (longitudinal benchmarking). Benchmarking may also be performed at the system or component level.

Building Automation System (BAS): A system that is designed to control building HVAC operations and indoor climate.

Current Facility Requirements (CFR): A document that details the current functional requirements of an existing facility and the expectations of how it should be used and operated. This includes goals, measurable performance criteria, cost considerations, benchmarks, success criteria, and supporting information to meet the requirements of facility occupants, users, and owners.

Energy Information System (EIS): Software, data acquisition hardware, and communication systems used to store, analyze, and display building energy data. EIS is a subset of EMIS, focused on meter-level monitoring at the whole building and submeter levels.

Energy Management Information System (EMIS): A broad family of tools and services to manage commercial building energy use. These technologies include, for example, the energy information system, equipment-specific fault detection and diagnostic systems, benchmarking and utility tracking tools, automated system optimization tools, and building automation systems.

Energy Savings: A reduction in energy use often quantified by accounting for key normalization factors such as weather or hours of operation.

Energy use intensity (EUI): A unit of measurement that describes a building's energy use, relative to its size, on an annual basis. The common metric is kBtu/sf/yr.

Existing Building Commissioning (EBCx): A systematic process for investigating, analyzing, and optimizing the performance of building systems through the identification and implementation of operational improvements.

Fault Detection and Diagnostics (FDD) Software: FDD automates the process of detecting faults in systems and assists in diagnoses of their potential causes. FDD systems for HVAC generally use a set of "expert rules" that analyzes BAS and meter data to determine fault conditions. FDD is a subset of EMIS, focused on system-level monitoring using the BAS data.

Measurement and Verification (M&V): The process of using measured data and other operational information to confirm the energy savings from energy efficiency projects. The International Protocol for Measurement and Verification defines four standard M&V approaches.

Monitoring Action Plan: The Monitoring Action Plan (MAP) is the key document for defining the analysis that will occur during the MBCx process. The metrics, views, and analytics in the MAP will be made available through the EMIS. The MAP provides facility operators with a quick reference guide on what will be tracked to keep the HVAC and lighting control systems optimized over time.

Monitoring Based Commissioning (MBCx): MBCx is a process which maintains and continuously improves building performance over time. MBCx is defined as the implementation of an ongoing commissioning process with focus on monitoring and analyzing large amounts of data on a continuous basis.

Program Overview

[Delete gray highlighted instructional text for final MBCx Plan]

[Edit yellow highlighted text per your organizational needs.]

[Company Name] is implementing a Monitoring-based Commissioning (MBCx) process to maintain existing improvements and implement further improvements to building performance over time. Monitoring-based commissioning is defined as the implementation of an ongoing commissioning process with focus on monitoring and analyzing large amounts of data on a continuous basis. The key elements of MBCx are as follows:

- collection of building data, typically energy metering and data from energy-consuming systems;
- data analysis through automated fault detection and diagnosis (FDD) and/or energy information systems (EIS) to identify issues and opportunities, and
- a process for implementing improvements based on the analytics and verifying savings.

[Company Name] is implementing a monitoring-based commissioning (MBCx) program to help meet these goals [edit below]:

1. Achieve energy and operational savings (XX% reduction in energy use intensity (EUI) relative to the baseline year of XXXX)
2. Maintain building performance (no increase in energy use relative to baseline year of XXXX)
3. Reduce hot/cold calls by XX% relative to baseline year of XXXX
4. Meet key performance criteria [list here, such as ventilation rates, and space pressurization]

XX buildings (XX% of the XX sq ft building portfolio) will undergo MBCx. The buildings selected for MBCx include: [list here]. These buildings were selected as good candidates for MBCx because the HVAC systems are not planned to be replaced in the next few years, the buildings have direct digital control systems in place, and there are existing whole building interval meters in place.

This MBCx Plan describes how performance will be tracked using an Energy Management and Information System (EMIS) to ensure intended building performance. The MBCx program consists of three key phases which correspond to the sections in this MBCx Plan:

Section 1: MBCx Planning Phase: This section establishes the technical plan and scope for how monitoring-based commissioning will be implemented using either a new or previously installed EMIS. The monitoring activities (key performance indicators and analytics) are defined in the Monitoring Action Plan (MAP) to help meet and maintain the current facility requirements. The metrics, views, and analytics in the MAP will be made available through the EMIS.

Section 2: EMIS Configuration Phase: This section is intended to be used for EMIS planning and installation. However, the concepts can be routinely used throughout the MBCx process to ensure data quality. The section provides guidance on establishing reliable and accurate data streams for a new or previously installed EMIS to support an MBCx program. A focus on "commissioning the EMIS" ensures that the MAP is supported by reliable data that aligns with program needs.

Section 3: MBCx Implementation Phase: This section defines how MBCx will be carried out and integrated into ongoing operational practices. The MAP defined in Section 1 serves as the master plan for how the EMIS will be used during MBCx implementation, and will support corrective actions and program reporting.

Table 1 defines the steps that [Company Name] will take to implement the MBCx process over the next [insert timeframe]. Numbering in Table 1 corresponds to sections within this MBCx Plan.

[To use Table 1, delete any rows that do not apply to your MBCx process]

Table 1. Monitoring-Based Commissioning Process

Section 1: MBCx Planning Phase
1.1 Collect building documentation and create/update current facility requirements (CFR)
1.2 Define high priority systems for performance monitoring
1.3 Create a Monitoring Action Plan (MAP)
1.4 Specify or enhance an Energy Management and Information System (EMIS)
1.5 Create a Training Plan
Section 2: EMIS Configuration Phase
2.1 Define data configuration requirements
2.2 Calibrate critical sensors
2.3 Perform EMIS data quality checks
2.4 Create an EMIS user interface
2.5 Configure the FDD
2.6 Configure energy savings and anomaly tracking
Section 3: MBCx Implementation Phase
3.1 Identify issues and opportunities using EMIS and the Monitoring Action Plan
3.2 Investigate root cause for prioritized issues
3.3 Identify and implement corrective actions, and update facility documentation
3.4 Verify performance improvement
3.5 Implement reporting, documentation, and training

The MBCx program will be carried out by the team defined in Table 2.

Table 2. MBCx Team Members

Name	Title	Role
[insert]	Energy Manager	Manages the project, oversees planning and implementation of MBCx, and communicates progress and outcomes to management.
[insert]	Building Engineer	Assists with EMIS installation and is involved in the development of the Monitoring Action Plan. Familiar with the building's control system and architecture.
[insert]	Owner IT Representative	Supports EMIS design and setup with regard to IT networks, data transfer processes, and network cybersecurity.
[insert]	EMIS Integrator	In this MBCx program, the EMIS vendor serves as the system integrator. Responsible for setting up the EMIS according to the Monitoring Action Plan and installing and configuring systems to communicate and transfer data. Responsible for supporting development and executing the EMIS Configuration Phase.
[insert]	Commissioning Provider	Responsible for writing the Monitoring Action Plan with support from building engineers and EMIS Integrator, and with oversight of the Energy Manager. Assists in the MBCx Planning Phase and supports the team during MBCx Implementation.

Appendix A contains the full schedule for MBCx Plan implementation with responsible team member assignments for each step in the MBCx Plan.

Section 1: MBCx Planning Phase

This section establishes the technical plan and scope for how monitoring-based commissioning will be implemented using either a new or previously installed EMIS. The technical monitoring activities (key performance indicators and analytics) are defined in the Monitoring Action Plan (MAP) to help meet and maintain the current facility requirements. The metrics, views, and analytics in the MAP will be made available through the EMIS.

1.1 Collect Building Documentation and Create/Update Current Facility Requirements (CFR)

[Review and edit this section based on whether there is an existing CFR that will be reviewed or a new CFR will be created as part of this MBCx program]

Normal operating ranges for each monitored system are documented in the current facility requirements (CFR).[1] The CFR includes: [edit the following list] indoor temperature and humidity requirements in occupied and unoccupied mode, building operating hours, requirements for special use areas, and other key operational parameters. The CFR will be used to inform the development of the MAP (Section 1.3), as EMIS metrics and analytics will be included to check that the CFR is being met. Another document that will guide the development of the MAP is the current sequence of operations, as faults will be identified when systems are not operating per the intended sequences.

1.2 Define High Priority Systems for Performance Monitoring

In this MBCx Plan, defining high priority systems for performance monitoring narrows the focus of monitoring to the more critical systems and issues. Priority will be given to tracking performance of measures implemented in prior commissioning efforts as well as other key energy-saving features. [Include a list or reference documents of major findings from any commissioning processes or energy audits in the past five years].

Table 3 indicates the scope of EMIS application for the MBCx project, noting which building systems will be covered by the EMIS.

Table 3. EMIS Scope for MBCx

Systems Monitored	Within scope for MBCx program? (check box)
Chillers and cooling towers	☐
Boilers	☐
Air handlers	☐
Terminal units	☐
Packaged HVAC	☐
Lighting	☐
Commercial refrigeration	☐
Whole building energy meters	☐
Energy submeters [specify areas / end uses]	☐
Other: define	☐

[1] The CFR is sometimes referred to as Owner's Operating Requirements. The California Commissioning Collaborative has a template and sample Owners Operating Requirements document available for adaptation. See http://www.cacx.org/resources/rcxtools/templates_samples.html.

1.3 Create a Monitoring Action Plan (MAP)

[This section provides guidance on establishing a robust monitoring plan that utilizes a new or previously installed EMIS to support an MBCx program. The MAP should be used throughout ongoing implementation of a MBCx process to provide structure for how the EMIS is utilized for maintaining and improving building operations.]

The MAP is the key document for defining the analysis that will occur during the MBCx process. The metrics, views, and analytics in the MAP will be made available through the EMIS. The MAP has been developed to provide facility operators with a quick reference guide on what will be tracked in order to keep the HVAC and lighting control systems optimized over time. It covers the following topics:

- Key performance indicators and analytics that will be tracked in the EMIS
- The EMIS functionality that will be used to track them
- What to review in the EMIS to find performance issues or areas for improvement

The MAP is included in Appendix B. For support with analysis methods, reference Lawrence Berkeley National Laboratory's *Energy Information Handbook* [2] and *Using EMIS to Identify Top Opportunities for Commercial Building Efficiency.*[3] The MAP may be updated through the course of the MBCx program as needed.

1.4 Specify or Enhance EMIS

[Once the MAP is completed, an existing EMIS may need to be updated to meet its needs. In the case of a newly specified EMIS, the procurement specification[4] should include reference to the MAP. This section, and its title, may be adapted based on whether there is a preexisting EMIS. The EMIS vendor name may also be included here, if known.]

Specifying and selecting an appropriate EMIS to meet the needs defined in the MAP requires attention to who is expected to use the system and how it will be used. The EMIS will be used by staff to perform the following MBCx activities [update list below as needed]:

- **Identify issues and opportunities using the EMIS:** For a quick summary view at a portfolio level, color-coded anomaly conditions and automated analysis within the EMIS will be used to identify and prioritize areas for improvement. Charts (such as load profile charts, for example) may also be created for manual/visual review of energy performance.
- **Root cause analysis and investigation:** After system performance issues have been detected, analytic results will be reviewed within the EMIS, through the building automation system and with field observation to pinpoint a specific resolution.
- **Identify and implement corrective actions:** A plan to resolve the issues will be developed and implemented using the EMIS as a support tool to feed issues into the work order system.
- **Reporting:** The EMIS will be utilized in reporting results of MBCx efforts on a regular basis, through metrics tracking or formal measurement and verification of energy savings.

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[2] *Energy Information Handbook: Applications for Energy-Efficient Building Operations*. Available at: **https://publications.lbl.gov/islandora/object/ir%3A157152/datastream/PDF/download/citation.pdf**.

[3] *Using EMIS to Identify Top Opportunities for Commercial Building Efficiency.* Available at: **http://eis.lbl.gov/pubs/top-opp.pdf**.

[4] *EMIS Specification and Procurement Support Materials*. Available at: **http://betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/emis_proc_spec_BBA_FINAL_021815_508.pdf**.

[Company Name] has chosen to implement an EMIS with functionality as noted in Table 4 below (see Glossary for the EMIS Category definitions).

Table 4. EMIS Selected

EMIS Category	EMIS Attributes
Energy Information System (EIS)	Meter data analytics Automated measurement and verification (M&V) using interval meter data
Fault Detection and Diagnostics (FDD)	Smart alarms programmed into the BAS Fault detection software using standard and custom algorithms
Automated System Optimization (ASO)	System-level real-time optimization routines

1.5 Create a Training Plan

An MBCx Training Plan will be created, defining training for new and existing staff on using the EMIS, implementing the MAP, and conducting any required training when system settings are changed. The topics covered in the Training Plan will include the following [update list below as needed]:

- CFR and control sequences of operation
- Sensor calibration
- Troubleshooting data quality issues
- EMIS capabilities and navigation
- Using the MAP
- Training on building systems' improvements

The training plan will include details of schedule and responsibilities for any planned training.

Section 2: EMIS Configuration Phase

[This section provides guidance on establishing reliable and accurate data streams for a new or previously installed EMIS to support an MBCx program. Basic security, communications, and other general EMIS specification requirements are assumed to have been addressed prior to installation. However, data quality issues can occur at any time, so these activities may be repeated periodically.]

In order to support a successful MBCx project it is critical to establish robust monitoring tools to support continuous energy and system analysis. This process goes far beyond simply installing hardware and software; the EMIS must be commissioned to ensure that the right data are accurately and reliably gathered, and to ensure that software programming is aligned with MBCx program goals. This section defines the planned steps for configuring and commissioning the EMIS, including the following:

- Define data configuration requirements
- Calibrate critical sensors
- Perform EMIS data quality checks
- Create an EMIS user interface
- Configure the FDD
- Configure energy savings and anomaly tracking

2.1 Define Data Configuration Requirements

Appendix C (Data Configuration Requirements) outlines the data types that will be monitored using the EMIS to support the MBCx program. In addition to configuring an ongoing data stream, there will be certain meters for which historical data will also be imported (for example, to provide a historical energy baseline). Data point naming/tagging will follow consistent, transparent naming conventions.

2.2 Calibrate Critical Sensors

Wherever possible, meters/sensors will be calibrated, and values derived from interval meters and submeters will be cross-checked against monthly billing data to ensure consistency. The most critical points for calibration are [modify list based on system types defined in Table 3]:

- Outside air temperature
- Air handler supply air temperature, return air temperature, and mixed air temperature
- Chilled water supply and return temperatures
- Hot water supply and return temperatures

[The California Commissioning Collaborative provides a Calibration Plan template and sample document. See **http://cacx.org/resources/rcxtools/templates_samples.html**]

2.3 Perform EMIS Data Quality Checks

EMIS data being used for the MBCx program (documented in Appendix C) will be quality-checked, with particular attention to the following potential issues [update list below as needed]:

- Data values falling outside the range of an installed meter or sensor
- Meters installed incorrectly
- Insufficient data capture (e.g., memory too small, sample rate too high, data gaps due to power outage and no cache memory at meter)

- EMIS not reporting data
- Misleading data labeling
- Data interval insufficient for analysis purposes
- Sum total of submeters does not add up to total of upstream meter(s) (missing or erroneous data streams)
- Imported weather data are not representative of local climate

In many cases issues may be visually identified using EMIS charts, and cross-comparison and manual calculations may be helpful. Any issues will be documented, with follow-up actions and responsibilities identified.

2.4 Create an EMIS User Interface

Once data quality has been checked, EMIS dashboards and drill-down views will be configured for the MBCx program, to support the MAP and other general reporting needs. EMIS dashboards will often have a high degree of flexibility, and may be configured differently for different users. Default dashboard design will be confirmed with or specified to the EMIS vendor, and the required information and images will be provided to the EMIS vendor. Where dashboards may be user-customized, the EMIS vendor will provide instructions to the facility's lead user and other users as needed. These features will be incorporated into the user interface [update list below as needed]:

- Building name and geographical location
- Simple chart display or summary table indicating key performance indicators
- Sorting of sites within a portfolio (if applicable)
- Navigation from main landing page to specific buildings/meters/charts/etc.
- Summary of outstanding issues or alerts
- Savings summary data for MBCx program [possibly covering multiple affected buildings], showing progress toward the project savings target
- Progress toward long-term organizational goals

2.5 Configure the Fault Detection and Diagnostics

[This section may be omitted if an FDD tool is not applicable to this program]

Once the FDD tool has been configured to import BAS data points, calibration has been confirmed, and data storage and communications have been established, the next step in configuring FDD is to select and implement FDD rules. To manage operator workload and effectively implement FDD for the MBCx program, rules will initially be limited to certain system or fault types [optional]. The MAP will be used to inform the specific rules to be implemented, and fault thresholds will be tuned as part of the implementation process.

At time of installation, a schedule will be set for periodic/ongoing refinements, for example regular check-ins with the FDD vendor/consultant for reviewing or adding FDD rules. Also, the fault prioritization method (e.g., based on cost impact, occupant impact, etc.) and response plan will be tailored to MBCx program objectives and resources.

2.6 Configure Energy Savings and Anomaly Tracking

[An advanced EIS can be used for two key energy management functions: (1) to measure energy savings relative to a historical baseline, and (2) to alert users when energy use exceeds current expectations

(tracking “anomalies”). This section provides guidance in configuring an advanced EIS for these two functions to support an MBCx program, and refers to more detailed tables in Appendix D. Some EIS do not include baseline model capabilities, but may be configured with simpler energy charts and reports that can also be used to support MBCx program tracking.]

Once meter data streams have been established as defined in Appendix C, MBCx energy savings tracking will be configured using the parameters in Appendix D. Table 5 below provides a summary of the energy savings and anomaly tracking that will be established for this program. [Table 5 includes examples. Adapt as applicable.]

Table 5. Summary of Planned Energy Savings and Anomaly Tracking

Type	Data	Purpose	Baseline period
Energy Savings Tracking	Whole building electric (15-min)	Progress toward corporate 15% savings goal	1/1/15–12/31/15
Energy Savings Tracking	Whole building electric (15-min)	MBCx program savings	2/01/16–1/31/17
Anomaly tracking	Whole building electric (15-min)	Maintain savings after MBCx complete	TBD upon MBCx completion

Section 3: MBCx Implementation Phase

[This section describes key steps in the ongoing implementation of the MBCx Plan. The Monitoring Action Plan (MAP) serves as the master plan for how the EMIS will be used during MBCx implementation, and will support corrective actions and program reporting.]

Once the EMIS has been commissioned and any periodic review/update requirements have been defined, the MBCx program moves to the Implementation Phase. Refer to the MAP as the key document defining the monitoring phase activities using the EMIS. The following steps define the ongoing MBCx Implementation Phase:

- Identify issues and opportunities using EMIS and MAP, and identify highest priority issues for further action
- Investigate root cause for prioritized issues
- Identify and implement corrective actions, and update facility documentation
- Verify performance improvement
- Implement reporting, documentation, and training

These MBCx Implementation steps are further defined in the following sections.

3.1 Identify Issues and Opportunities Using EMIS and the Monitoring Action Plan

The MAP defines the metrics and analytics that will be included in the EMIS to help identify issues and opportunities for improvement. Using the EMIS to identify issues can consist of a combination of FDD analytics and and/or manual review of performance indicators and automated charts. The issues and opportunities identified will be compiled in an Issues Log, prioritized based on severity and cost. [The California Commissioning Collaborative has a sample Issues Log template that may be downloaded at **http://cacx.org/resources/cxtools/index.html**]

3.2 Investigate Root Cause

After issues or opportunities are found using the EMIS, the cause of the problem will be determined by reviewing BAS trends, setpoints, and controls programming, and through field investigation of equipment. The results will again be tracked in the Issues Log.

3.3 Identify and Implement Corrective Actions, and Update the Facility Documentation

In planning the MBCx process, it is critical to define how the analytics will be acted upon and used to support building operation. The plan for follow-up and corrective actions for the issues found through the MBCx process are as follows: [update list below as needed]:

- Monthly team meetings (or more frequent as needed) with energy manager and facilities staff to communicate results of performance monitoring and to review/prioritize any identified issues
- Prioritize issues based on relative severity and cost, as provided by the EMIS savings estimates
- Cost thresholds set with management for approval of corrective actions
- Improvements identified and approved will be manually input into the work order system. Future system enhancements may include automated work order generation. [If the organization has an established work order protocol and/or computerized maintenance management system (CMMS) it may be referenced here.]

The corrective actions implemented may be a maintenance/repair action, setpoint modification, control sequence modification, or recognition of needed capital improvements (although capital improvements

may be outside of the MBCx process). Implementation and future recommendations will be tracked in the Issues Log, and changes will be updated in relevant building documentation.

3.4 Verify Performance Improvement

Once measures are implemented, they will be verified to ensure proper implementation. Then FDD rules or performance indicators will be updated to detect degradation or failure of the measure automatically. [Insert requirements and location for documenting performance verification activities here, if applicable.]

EMIS metering and analysis capabilities may be utilized to automatically quantify energy and cost savings (see Section 2.6 and Appendix D for the plan for configuring the EMIS to track energy savings and identify energy anomalies).

3.5 Implement Reporting, Documentation, and Training

Documentation will aid in the persistence of benefits from the MBCx process. The following documents will be updated by the MBCx team on a quarterly basis:

- Issues Log
- Sequences of operation and controls as-built documents
- As-built and record documents for the building
- Updates to the CFR if facility needs have changed
- Training records
- Energy savings and return-on-investment reporting

[Insert a description of the documents' location]

Appendices

Appendix A: Schedule and Responsibilities

MBCx Activity	Description [edit to meet needs]	Responsibility	Due Date
Section 1: MBCx Planning Phase			
1.1 Collect building documentation and create/update current facility requirements (CFR)	Normal operating ranges for each monitored system are documented in the CFR. At a minimum, the CFR should include indoor temperature and humidity requirements in occupied and unoccupied mode, as well as the building operating hours. The CFR should also include requirements for special use areas. The intended control sequences, along with the CFR, will be used to inform selection of monitoring and analytics.	Building energy managers and engineers, and MBCx providers	XX/XX/XX
1.2 Define high priority systems for performance monitoring	High priority issues include maintaining performance of corrective actions implemented through a prior commissioning project, systems that routinely have performance issues, and other key energy-saving features. [a prior commissioning report may be referenced here, if applicable]. The high priority systems for monitoring will be included in the Monitoring Action Plan.	Building energy managers and engineers, and MBCx providers	
1.3 Create a Monitoring Action Plan (MAP)	The Monitoring Action Plan (See Appendix B) defines what key performance indicators (KPIs) and analytics will be tracked in the EMIS, the EMIS functionality that will be used to track, and how to review the EMIS to find performance issues or areas for improvement. This is the key document for defining ongoing analyses associated with MBCx.	Building energy managers and engineers, and MBCx providers	
1.4 Specify or enhance energy management and information system (EMIS)	EMIS has been selected based on MBCx program scope, MAP, and organizational needs and resources. [or] The existing EMIS will be utilized [specify upgrades to existing EMIS and hardware if applicable]	Building energy managers and engineers, and MBCx providers	
1.5 Create a Training Plan	An MBCx Training Plan has been developed, covering: sensor calibration, troubleshooting data quality issues, EMIS capabilities and navigation, use of the MAP, and training on building systems' improvements.	Building energy managers and engineers, and MBCx providers	

Section 2: EMIS Configuration Phase			
2.1 Define data configuration requirements	All existing meters, BAS controls, and any other potential data sources or metering improvements have been identified. Data configuration requirements are documented in Appendix C.	Building energy managers and engineers	
2.2 Calibrate critical sensors	For the most critical monitored points, sensors are calibrated, such as outdoor air temperatire, air handler supply air temperature, return air temperature, mixed air temperature, chilled water supply & return temperatures, hot water supply & return temperatures. A list of points, acceptable ranges, and frequency of calibration has been compiled for each major HVAC system. [Refer to a calibration plan here, if applicable. An example calibration plan template may be downloaded at **www.cacx.org**.]	Building engineers and contractors	
2.3 Perform EMIS data quality checks	Data quality checks have been performed, including: [Include details from Sec 2.3 here as applicable.]	EMIS vendor and MBCx providers	
2.4 Create EMIS user interface [or adapt existing EMIS interface for MBCx program]	EMIS dashboards have been configured for the MBCx program, to include dashboard variations for different users. Default dashboard design has been finalized. Where dashboards may be user-customized, the EMIS vendor will provide instructions to the facility's lead user and other users as needed.	EMIS vendor, MBCx providers, and system integrator	
2.5 Configure the FDD	FDD rules have been programmed. FDD rules will initially be limited to certain system or fault types [optional]. The MAP has been used to inform the specific rules to be developed. At time of installation a schedule will be set for periodic/ongoing refinements; for example, regular check-ins with the vendor/consultant and a schedule for reviewing or adding FDD rules. Also, the fault prioritization method (e.g., based on cost impact, occupant impact, etc.) and response plan has been tailored to MBCx program objectives and resources.	EMIS vendor, MBCx providers, IT engineers	
2.6 Configure energy savings tracking	Historical or current performance baselines/benchmarks for all relevant metrics in the Monitoring Action Plan (Appendix B) have been set, from which deviations will be measured. Baselines will generally be set based on the previous 12-month period.	EMIS vendor and MBCx providers	

Section 3: MBCx Implementation Phase			
3.1 Identify issues and opportunities using EMIS	The core of MBCx is implementation of the Monitoring Action Plan. Key performance indicators (KPIs) and analytics will be reviewed in the EMIS to help identify issues and opportunities for improvement. Results will be compiled in an Issues Log.	Building engineers and MBCx providers	
3.2 Investigate root cause	After issues or opportunities are found using the EMIS, the cause of the problem will be determined by reviewing BAS trends, setpoints, and controls programming, and through field investigation of equipment. The results will be tracked in the Issues Log.	Building engineers and MBCx providers	
3.3 Identify and implement corrective actions, update facility documentation	The corrective actions implemented may be in the form of a maintenance action, setpoint modification, control sequence modification, or recognition of needed capital improvements (capital improvements may be outside of the MBCx process). Implementation will be tracked in the Issues Log, and changes will be updated in relevant building documentation.	Building engineers, contractors, and MBCx providers	
3.4 Verify performance	To verify that the building systems are operating as intended, energy savings will be estimated at whole building level. EMIS metering and analysis capabilities will be utilized to automatically quantify energy and/or cost savings (see Appendix D for guidance on configuration of the EMIS to track energy savings and identify energy anomalies).	Building energy managers and engineers, and MBCx providers	
3.5 Implement reporting, documentation, and training	The following documents will be updated by the MBCx team on a quarterly basis: Issues Log; Sequences of operation and controls as-built documents; as-built and record documents for the building; updates to the CFR if facility needs have changed; training records; energy savings and return-on-investment reporting.	Building energy managers and engineers	

Appendix B: Monitoring Action Plan

[To use the Monitoring Action Plan template, review each row and decide if each is an appropriate metric to track at your facilities. The metrics in this list are examples that should be tailored to your organization's needs. Delete any rows that are not planned for execution as a part of the overall monitoring-based commissioning strategy.]

METER-LEVEL KEY PERFORMANCE INDICATORS (KPIS)		
Checkpoint / Metric	**EMIS View**	**What to look for**
Annual energy use with normalizing factors such as gross floor area and heating degree day (HDD) / cooling degree day (CDD)	Annual EUI in kBtu/sq ft or by fuel ENERGY STAR portfolio manager benchmark score to gauge climate-normalized performance relative to peers	Rank portfolio and review outliers
Monthly energy use with normalizing factors such as gross floor area and HDD/CDD	Monthly EUI in kBtu/sq ft or by fuel	Compare to previous month or previous year of the same month
Daily electricity KPI: (Total bldg. kWh/day)/(Avg daily outdoor air temperature	Min/max/average/current daily reading	Establish facility benchmarks after commissioning
Daily gas KPI: (Total therms/day)/(Avg daily outdoor air temperature)	Min/max/average/current daily reading	Establish facility benchmarks after commissioning
METER-LEVEL ANALYTICS		
Checkpoint	**EMIS View**	**What to look for**
Schedules	Use heat map and/or load profile graphs with filtering for weekday/weekend/holiday	Confirm that time-of-day schedules meet the current facility requirements. Check weekends and holidays for scheduling improvement opportunities.
Baseload	Use heat map and/or load profile graphs with filtering for weekday/weekend/holiday	Compare to the peak load to assess the after-hour setback.
Energy signature	Hourly energy consumption vs. hourly outside air temperature (or daily energy consumption vs. degree days). Some EMIS automatically compare the energy signature metrics to industry benchmarks.	Weather-dependency of loads, balance point temperature at which heating or cooling starts), and baseload; High heating energy use in summer may be associated with simultaneous heating and cooling.
Load shape	24-hour demand plot, min/max/avg by day type	Start time, stop time, weekend, and holiday scheduling

Energy anomaly	Flag when energy use is outside the modeled prediction (see Appendix D for modeling instruction)	Energy use outside of a defined threshold of performance (+/- 10% for instance)
Meter data	Flag when meter has failed. A time series chart may be used to visually identify a gap.	Large or repetitive (i.e., at regular intervals) gaps in energy data
Energy Savings/M&V	The cumulative annual energy savings, or % change in energy use	Model statistics are within the thresholds set
SYSTEM-LEVEL KEY PERFORMANCE INDICATORS		
Checkpoint	**EMIS View**	**What to look for** (Establish facility benchmarks after commissioning)
BAS Override Report	Building automation system override summary	Identify overrides that should not be in place. Overrides often point to larger system control or performance issues.
BAS Alarm Report	List of recent alarms	Identify patterns in which systems are alarming. Potentially create FDD rules to help troubleshoot alarms.
Occupant Comfort Index (%)	% of operating hours spent within zone target temperature	Measure for each zone or collection of zones. Track average, minimum, and maximum values for each building.
Cooling Plant Efficiency (kW/ton)	kilowatt (kW)/ton daily profile Daily Average (kW/ton)/ton kW of entire plant preferred, but pump metering is not always available.	Will vary based on load. Review kW/ton vs. ton plots over time to identify performance drift.
Heating Plant Efficiency (%)	Btu per hour (out) / Btu per hour (in) Review daily profile.	Will vary based on load. Review efficiency vs. load plots over time to identify performance drift.
Fan System Efficiency (%)	kW of supply/return/exhaust fans per cubic feet per minute (cfm) of airflow	Will vary based on load. Look for variance between air handlers or performance drift.
Chilled water delta T	Daily average difference in chilled water supply and return temperatures	If there is an insufficient temperature difference, investigate over-pumping or other issues.

FAULT DETECTION AND DIAGNOSTICS	
Faults [This list is a starting point for including the most critical faults in the FDD software. Many additional faults may be detected. Update per actual implementation.]	**FDD Tool Analysis** [Once the FDD has been installed and commissioned, update per actual implementation of rule in the FDD software so the table serves as a reference.]
General Faults	
Schedules (air handling units, terminal units, chillers, boilers, pumps, cooling towers, plug and process loads, and garage exhaust fans)	Check if equipment is operating out of hours.
Manual override (air handling units, terminal units, chillers, boilers, pumps, and cooling towers)	Identify overrides that should not be in place.
Controllers (actuators/valves/speed drives)	Compare controller output setpoints to the actual condition to find failed devices. Determine the stability of controllers.
Dampers (air handling units, terminal units)	Identify if a damper is stuck open, closed, or at a fixed position, or leaking (i.e., compare mixed air temp to return air temp with outdoor air damper closed).
Cooling/heating/precooling/preheating/ reheating valve and coils	Identify if a valve is stuck or leaking. Identify a fouled or blocked coil. (i.e., a temperature difference exists across a coil when a valve is shut or not achieving a desired temperature drop across a coil when a valve is open.)
Air Handler Faults	
Economizer operation/use	Detect if the rooftop unit (RTU) or air handling unit (AHU) is not economizing when it should. Detect if the RTU/AHU is economizing when it should not; (i.e., calculate relevant theoretical outdoor air ratio with outdoor air temperature, return air temperature, and mix air temperature). Detect if the economizer lockout setpoint is too high or low.
Ventilation	Ensure that the ventilation rate is adequate. Detects if the RTU/AHU is bringing in too much outside air when not in economizer mode.
Simultaneous heating and cooling	Detect if unnecessary heating, economizer cooling, and/or mechanical cooling happen at the same time.
Discharge air temperature reset	Identify if the discharge air temperature setpoint is a fixed value or does not vary through the reset range. Confirm that the point is not frequently pegged to an upper or lower limit.

Duct static pressure reset	Identify if the duct static pressure setpoint is a fixed value or does not vary through the range. Confirm that the point is not frequently pegged to an upper or lower limit.
Sensors	Critical sensors: Outdoor air, discharge air, return air, and mixed air temperature; wet bulb temperature or relative humidity; pressure, airflow rates. Detect if the sensor is outside of a feasible range, flat-lining, bias, drift, or failure
Dirty Filter	Determine if the air filter needs replacement (i.e., filter pressure drop outside specified range)
Variable Air Volume (VAV) box faults	
Sensors	Critical sensors: space temperature, relative humidity, carbon dioxide, airflow rate Detect if the sensor is outside of a feasible range, flat-lining, bias, drift, or failure.
Thermostat occupied/unoccupied cooling/heating setpoints	Detect if the space cooling/heating setpoints deadband is not great enough (i.e., less than 3°F).
Thermostat space temperature	Identify if zones are outside of an acceptable temperature range over a period of time. Indicates if the space is over/under cooling/heating or if there is a leaky/stuck VAV damper.
VAV supply airflow	Detect if supply airflow is adequate to the zone (i.e., supply airflow is below the setpoint while the supply damper fully open). Detect if supply airflow is constantly at maximum flow.
Chilled water plant faults	
Sensors	Critical sensors: Chiller, and cooling tower leaving and return water temperatures; chilled water flow rate; pressure. Detect if the sensor is outside of a feasible range, flat-lining, bias, drift, or failure.
Chilled water plant lockout	Identify if the lockout temperature is too low.
Chiller leaving water temperature reset	Identify if the chiller leaving water temperature setpoint is a fixed value or does not vary through the reset range.
Tower leaving water temperature reset	Identify if the tower water temperature setpoint is a fixed value or does not vary through the reset range.
Hydronic differential pressure reset	Identify if the hydronic differential pressure setpoint is a fixed value or does not vary through the reset range.
Chiller short cycling	Identify if the chiller is cycling too frequently.
Cooling tower fan cycling	Identify if the fan is cycling too frequently.
Hot water plant faults	
Sensors	Critical sensors: Boiler leaving and return water temperatures; hot water flow rate; pressure. Detects if the sensor is outside of a feasible range, flat-lining, bias, drift, or failure.
Hot water plant lockout	Identify if the lockout temperature is too high or if the boiler is in operation when no heating load exists.

Boiler leaving water temperature reset	Identify if the boiler leaving water temperature setpoint is a fixed value or does not vary through the reset range.
Hydronic differential pressure reset	Identify if the hydronic differential pressure setpoint is a fixed value or does not vary through the reset range.
Boiler short cycling	Identify if the boiler cycles on and off too frequently.

APPENDIX C: Data Configuration Requirements

[Multiple tables may be necessary if installing EMIS for a portfolio, or a separate spreadsheet may be helpful. Example data streams to be defined in this table include: whole building electric/gas consumption; end-use submetering; chilled water; hot water or steam; BAS data; weather data; and calculated points. Refer to the Monitoring Action Plan to inform the required data points; this is particularly helpful for prioritizing key meter and BAS points to pull into an EIS or FDD. An industry resource such as Project Haystack may be a useful reference for point naming conventions]

#	Point ID	Trend Status				Sampling Rate		Calibration Checked (date)	Tied to EMIS?	EMIS Reading Confirmed
		Pt Avail. in BAS?	In Trend?	Reposi-tory Enabled	New Pt Needed?	Desired	Done			
CHILLED WATER										
CH-01										
1	CHWR1-gpm									
2	CHWS1-T									
3	CH1 motor kW									
4	CWS1-flow									
5	CWR1-T									
6	GP-1 spd (%)									

This is an excerpt with sample entries. See the attachment below for an editable version of the Data Configuration Requirements Table

Monitoring Points Definition (Stum).xls

APPENDIX D: Energy Modeling Requirements

[Many advanced EIS can be used for two key energy management functions: (1) to measure energy savings relative to a historical baseline, and (2) to alert users when energy use exceeds current expectations (tracking "anomalies"). This appendix provides guidance in configuring an EIS for these two functions to support an MBCx program, and includes a summary table with accompanying descriptions of table content. Some EIS do not include baseline model capabilities but may be configured with simpler charting/summary features to support MBCx program tracking and reporting. The table below has been created with some example content, for guidance purposes.]

In addition to monitoring savings against a historical baseline, EMIS will be configured with a more recent baseline which represents current "expected" energy use. A baseline model for expected energy consumption can be used for the purpose of alerting for anomalies that can indicate faults or significant operational changes. The table below describes requirements for developing baselines for both energy savings and anomaly detection. [Note: Creation of anomaly detection baseline may be delayed until after MBCx improvements have been implemented, to help staff track and maintain optimal performance.]

Baseline Purpose	Name	Model Period	Meter	Start Date (savings)	Other Key Dates	Model Type and variables	Approval Criteria
Energy Savings Tracking: progress toward corporate 10% savings goal	2015_HOURLY ELECTRIC BASELINE	1/1/15–12/31/15	A-468-U	1/1/16	Note date chiller replacement completed 6/13/16	Whole building electric, hourly, OAT-based regression	R^2 >0.7 CV(RMSE) <25% NMBE <0.5%
Anomaly tracking: Maintain savings after MBCx complete	EXPECTED_HOURLY	TBD upon MBCx completion	A-468-U	TBD	N/A	Whole building electric, hourly, OAT-based regression	TBD
[Add rows as needed]							

Description of Table Column Headings

Baseline Purpose

Define whether this baseline is being used to measure energy savings or to monitor ongoing performance to detect anomalies. Historical baselines may be created to quantify the energy savings relative to a prior calendar year, to quantify savings for this MBCx program, or for another purpose. Tracking performance to identify anomalies requires creation of a baseline model using recent energy consumption data, which may represent optimized energy performance following completion of an existing building commissioning project; this baseline is used to identify energy performance degradation that may happen over time.

Baseline Model Name

Give each baseline model a unique name that is easy to understand. Consider a naming convention that will allow for subsequent models to be added and easily distinguished from each other. This table may be used to describe multiple models for a given time period (e.g., electric, natural gas, water).

Baseline Model Period

For historical baselines, define the start and end dates for the historical baseline model, and include the reasoning, e.g., the 12-month period prior to the start of an EBCx project, or a calendar year used for corporate goal-setting. It may be of interest to define multiple baseline periods, but be careful to consider the added complexity and the risk of confusing users. For anomaly tracking baselines, define the start and end dates for the dynamic baseline model, and describe whether the baseline period is fixed or "rolling." Note: An EMIS may be restricted in how it can define model data periods; it is recommended to discuss EMIS capabilities with your vendor.

Applicable Meters

List meter numbers/names applicable for any baseline models being created.

Start Date for Measuring Savings (applies to energy savings baselines only)

Define the start date from which savings will be reported; for example, the first day of January, the date on which an EBCx project was considered complete, etc. An EIS may be configured to show savings in several ways; consider which is most important to users and which additional options may be desirable. For example, an Energy Manager may want to monitor return on investment for an EBCx project, while a CFO may be more concerned with meeting corporate goals against a 2014 calendar year baseline.

Other Key Dates to Note in the EIS (optional)

If EIS software has the capability to log significant dates, they may be defined here. For example, the start and end dates for projects or specific energy conservation measures, or to log the dates of significant equipment breakdowns. These can be helpful when viewing savings charts, as they help the user understand the known causes of energy use changes.

Define Baseline Model Type and Independent Variables

Note data frequency (e.g., hourly, daily, etc.). Ambient temperature is a common independent variable used in baseline models. Other independent variables may be considered, including occupancy levels and production volume. The level of specificity in defining model type can vary, and some experimentation may be required before achieving the required accuracy for a baseline model.

Baseline Model Approval Criteria

Note who will approve the historical baseline model, and on what criteria approval will be based. This may be specific threshold values for metrics such as CV(RMSE), NMBE, R^2, or other criteria.