Monitoring Based Commissioning for LEED Building Performance Optimization

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Synopsis

This document describes Monitoring-Based Commissioning (MBCx) as a method for ensuring optimized performance of LEED buildings during the first year of operation, utilizing synergies between building energy simulations, measurement and verification (M&V) and building commissioning (Cx). Monitoring-Based Commissioning is an up-coming LEED credit in the new USGBC LEED 2012, and is part of an industry-wide movement towards performance-based contracts of design and construction. It is currently the most comprehensive process that validates equipment and systems performances during first year operation period.

About the Authors

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Boban has over 20 years of experience in building systems commissioning. Boban's services focus around holistic approach to the building systems commissioning, combining building systems energy analysis and measurement and verification into the total building commissioning process. He is a member of the Board of Directors for the Building Commissioning Association Western Canadian Chapter.

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Introduction

MBCx is a relatively new process that involves energy sub-metering of major building systems and equipment, and the use of energy baselines from modeled data to identify deficiencies in building energy performance. In addition to energy data, typical control system data such as temperatures, flows, pressures, and equipment run statuses, are collected and analyzed to determine the source of deficiencies and for opportunities to further improve performance. Energy use and control system data can be collected and processed with an Energy Management System, to facilitate performance analysis and comparisons with benchmarks.

Other advantages as a by-product of the MBCx process are – the calculation of energy savings to determine the rate of return of the investment in improved efficiency, better training of building managers in the use and control of building systems, and a permanent monitoring system with ideal energy-use benchmarks, to ensure the long-term persistence of energy performance and to enable sensible decision making with respect to building maintenance programs, occupant awareness programs, and future improvements and retrofits.

The objectives of this document are to:

1. Propose a process for Monitoring Based Commissioning in the context of LEED, as a definitive tool for evaluating and optimizing energy performance of new buildings;
2. Identify the synergies between Energy Modeling, Measurement and Verification and Commissioning process required for a successful MBCx program;
3. Discuss implementing energy management techniques in the commissioning process;
4. Discuss data collection and validation;
5. Discuss metering requirements and meter calibration for adequate M&V;
6. Discuss energy modeling calibration and energy "baselining";
7. Discuss identifying deficiencies and taking corrective actions;

From Prescriptive-Based to Performance-Based Construction

A 2009 Natural Resources Canada study entitled "Do LEED-certified buildings save energy? Yes, but…" expanding on a 2008 study by the New Buildings Institute, "Energy Performance of LEED for New Construction Buildings," showed that while LEED buildings used on average 18-39% less energy than their conventional counterparts (depending on the method of comparison), 28-35% of buildings used more energy than their conventional counterparts. In addition, there was no correlation between energy performance and the number of LEED achieved energy credits, as well as no difference in energy performance between buildings that underwent basic commissioning (Cx) versus enhanced commissioning.

The reality is that the building construction process and the commissioning process only rarely include the consideration of energy performance targets. Ideal performance is predicted using energy modeling software, and it is assumed that this performance will carry into the actual building. Consequently, fine-tuning buildings for energy performance utilizing energy management techniques does not occur during the first few months to a year of operation. While commissioned equipment and systems may perform adequately in terms of meeting space comfort conditions, without monitoring and assessing building performance, buildings might fall short of the project's predicted energy performance. Even if buildings meet or exceed predicted performance, is this a result of overly generous modeling assumptions? Are buildings actually living up to their full potential?

The need for energy performance verification and post-construction optimization of LEED buildings is part of a greater industry trend towards performance-based construction contracts, and performance-based commissioning that extends into the operational phase of the building. The draft of the USGBC LEED 2012 program shows a new section entitled 'Performance', which includes prerequisites for water metering and building-level energy metering, and credits for Monitoring-Based Commissioning, advanced metering for water and energy, and "Reconcile Projected and Actual Energy Performance", in addition to the current commissioning prerequisite and credit. In a recent press release, the USGBC's Scot Horst, Senior Vice President of LEED had the following to say regarding the direction of the LEED program:

"LEED 2012 is the next step towards a global, performance-based application. In LEED 2012, a project's engagement with LEED will represent an ongoing commitment that is supported by a suite of performance management tools."

Designing and constructing buildings to performance targets requires measuring building performance in operation. Measurement and Verification (M&V) is the standard process for accurately evaluating building energy performance and is a credit in Canadian LEED NC 2009. The full M&V process (IPMVP Option D) consists of gathering actual energy and operational data, calibrating the proposed design and reference building energy models to the actual building use and operation, and re-calculating energy savings after calibration. Issues with building performance may be discovered during the calibration process if it is found that the calibrated model still outperforms the actual building despite eliminating variables such as weather and operational schedules.

In the typical M&V process, 1 year of data is gathered before model calibration, so performance issues are not determined until at least 1 year after building operation. Without the appropriate monitoring infrastructure (energy sub-metering), it may not be easy or possible to determine where in the building the issue is arising and whether it is due to modeling assumptions and approximations. LEED NC 2009 merely requires the development of an M&V plan, with no actual follow up required so it is very unlikely that buildings that achieve the M&V credit are actually going through the full exercise of accurately verifying performance, and even less likely that something is being done about performance issues. To reiterate, M&V is a process of measuring actual energy savings, and not a process of ensuring optimal performance.

Commissioning for Performance

A relatively new process for ensuring that new buildings achieve near-optimal performance is Monitoring-Based Commissioning (MBCx). MBCx makes use of energy metering information from electrical, gas and thermal meters, energy targets from energy models, and trend-logs of typical control system data to rigorously assess building performance, to identify performance discrepancies and to make corrections to building use procedures and control sequences to ensure near-optimal performance is achieved. MBCx *is* measurement and verification at a sub-system level, and it is also the process for achieving top building performance.

Due to the quantity of data to be analyzed and the complexity of energy calculations and benchmarking, an Energy Management System (EMS) can be an important tool in the MBCx process. An appropriate EMS will have the ability to – collect and log hundreds of DDC data points, perform mathematical functions to calculate energy use and performance metrics, conduct statistical analysis of data to create baseline equations describing performance variables in terms of weather conditions or system independent variables, reporting features to summarize data into easily understandable presentations. With such an EMS in place, the commissioning agent (CxA) can easily compare actual to predicted energy use in various forms (trend-logs, tables, charts), and with a database of all key DDC points available the details of the system operation are readily available and the source of performance discrepancies can be identified.

The CxA works with building O&M staff and DDC contractor to resolve issues that are undermining building performance. The close contact with O&M staff allows for hands-on training and a more thorough understanding of the building systems, energy-efficiency controls strategies, and use and maintenance of the EMS. Once the building operation is verified and fine-tuned and after the first year of operation, the official building energy savings and return on investment can be calculated and reported. The monitoring system remains in place for the life of the building, providing on-going performance verification and savings accounting, and providing a wealth of historical data for future energy management, efficiency retrofits or re-commissioning. The calibrated building energy model can also be retained for future use to determine the cost effectiveness of future retrofits, or to produce new energy baselines from increased building use or building expansion.

The MBCx Process

MBCx is an inherently multi-disciplinary activity requiring increased coordination between commissioning agents, mechanical, electrical and controls designers and contractors, energy modeling providers (EMPs), and building owners and operation and maintenance staff, beyond the typical commissioning process. It is the responsibility of the commissioning agent to understand the roles and responsibilities of each team member towards the MBCx program, and to facilitate communication and action items to ensure that implementation occurs smoothly. The experience required of the commissioning agent is also expanded to include knowledge of energy management, energy metering, energy modeling, and statistical analysis. Since commissioning agents with experience in all these areas are rare, they will have to draw on the expertise of the various team members to satisfy the MBCx requirements.

The key components of a measurement and verification system for MBCx are as follows:

- **Building DDC System** – used for implementation of energy-efficiency strategies and for collecting system process data;
- **Building Energy Model(s)** – used to create optimized control sequences, and calibrated to produce energy benchmark targets;
- **Energy End-use Sub-metering** – used to in conjunction with benchmarks to determine sub-system performance; used for long-term tracking of system performance;
- **Metering System Calibration Tools** – necessary to provide reasonable trust-worthy data for the MBCx investigation;
- **Data Acquisition System and Remote Database** – required to collect and store DDC and energy-meter data for EMS analysis;
- **Energy Management System and/or Analysis Software** – required to conduct energy calculations, to analyze trend-logs, and create energy and performance baselines through statistical calculations;

For each credit, LEED provides a list of requirements successfully achieve the credit intent. The following section presents such a list that would allow for full integration of MBCx in the design and construction process.

MBCx Requirements for New Construction:

1. *Include performance and metering system requirements in the Owner's Performance Requirements (Owner, CxA)*

Having overall building performance requirements (energy/CO_2/cost avoided), as well as intent for rigorous verification of performance through MBCx ensures that the design team must pay particular attention to performance outside of design conditions, and engage the building energy modeler to conduct parametric analysis of system options and control strategies.

2. *Establish key components of system efficiency in the Basis of Design (CxA, Consultants)*

Summarizing the key efficiency strategies early in the design process ensures that particular attention is paid to these features as the design progresses. The CxA can review these and provide design efficiency feedback if qualified to do so. Listing the strategies also helps in the development of the MBCx plan to determine metering requirements that ensure efficiency strategies are functioning properly.

3. *Create a MBCx plan including metering system design, and incorporate into projects specifications (CxA)*

The MBCx plan should reiterate the building overall performance targets as well as the strategies to meet these targets. The metering points to verify performance should be specified in detail (electric power, gas flow rates, thermal power, and additional flows and temperatures). The data acquisition and energy management systems should also be specified. Building energy model calibration should be included with the data required from the models to produce energy targets.

4. *Conduct one review design documents for further energy efficiency opportunities and one review of energy modeling inputs (CxA, EMP)*

In LEED EAc3 Enhanced Commissioning, a review of the design documents to ensure that they conform to the Owner's Project Requirements and Basis of Design. This is also a perfect opportunity to identify any additional performance opportunities through minor design adjustments – such as adding controls for certain spaces, recovering heat from cooling or refrigeration etc.

A review of the energy model should take place to build understanding and communication between the CxA and EMP, and to ensure that appropriate model inputs and techniques are being used based on design documentation.

5. *Develop detailed control sequences intended to optimize building energy efficiency (CxA, EMP, Consultants, DDC)*

One of the main reasons why buildings fail to live up to their potential is that control sequences are not implemented to maximize the building efficiency. Designer's typically provide general sequences to be interpreted and implemented by the building controls provider, without considering optimized performance. The controls provider then implements sequences that have been used successfully in other instances but may not be optimized for the particular project. Finally, when buildings are operational, many of these energy saving strategies are over-ridden by the building operators when they produce issues with the system or comfort complaints.

Detailed sequences of operation should be developed in tandem with the system design, with the designer's being aware of how the system will be operated through a range of operation and ideal reset, sequencing, and enabling sequencing determined through energy modeling or on advice from the CxA. These control sequences will then be implemented as intended through the engagement of the CxA with both the controls provider and the building operators.

6. *Conduct inspections to ensure correct meter installation (CxA)*

Monitoring system sensors must be inspected to ensure that they are in the correct location, labeled appropriately, and installed correctly. Sensors that are in the wrong location, not measuring the variable intended, or measuring poorly will undermine the accuracy of the metering system and the MBCx process.

7. *Field-calibrate all key building sensors and meters (CxA, DDC)*

It has been found that calibration of sensor readings is critical to an accurate monitoring system. Fortunately, sensor readings are typically consistent and can be adjusted based on calibration measurements. Temperature sensors can be verified against a calibrated hand-held sensor or with boiling or freezing water which are at known temperatures. Hydronic flow sensors can be calibrated based on fan and pump differential pressure measurements and pump curves, or with a clamp-on ultrasonic flow meter. Air flow meters can be calibrated with fan differential and fan curves, or duct traverse airflow measurements. Power meters can only be verified with a calibrated portable power meter.

8. *Install and commission Data Acquisition System (CxA, DDC)*

A data acquisition system can be used to collect data from the DDC system and remote system controllers and to send the data to remote databases used by an Energy Management System. All required measurement points must be checked to ensure that reasonable readings are being provided and that proper communication is occurring.

9. *Calibrate the design energy model during the first month of operation, and produce MBCx energy targets for all major use categories (EMP, CxA)*

Near the end of the construction phase, energy models can be partially calibrated by using actual equipment shop drawings. After the DAS is commissioned and functioning, with easy remote access to all key system data points and with some additional site measurements, energy models can be calibrated to closely represent actual building operation. Key items to consider in calibration are – plug load intensities and typical daily load profiles, typical lighting daily load profiles, outdoor air flow rates, actual water and air flows from balancing reports or site measurements, measured equipment power consumption or efficiency. Occupancy cannot be readily determined, but a good estimate based on discussion with the building operators is sufficient. The effect of occupant heat output on building energy use is typically small, compared to the effect of lighting and equipment energy, and outdoor air flows.

To produce immediate energy baselines after the proposed design model is calibrated, the modeled energy data, particularly weather dependent data, can be normalized for weather conditions through regression modeling. The goal of regression is to describe the relationship between a given dependent variable and some independent variable, such as heating energy as a function of outside air temperature, or lighting energy as a function of the time of day and solar radiation (if daylighting controls are used). Multivariable regression can produce very accurate baselines that can be used to compare actual and modeled daily profiles.

10. *Identify opportunities for improvement and resolve performance discrepancies (CxA, O&M, DDC)*

With energy benchmarks in place, discrepancies in modeled versus actual performance can be readily identified. Ideally, appropriate model and metering system calibration will rule out model and meter errors so the investigation can focus on the actual building operation. Optimization of control sequences will likely be required to reduce actual building energy if the building is over-consuming. Occasionally there will be issues with equipment but this is less common. Building operation staff can be engaged to discuss the identified issue and sequences can be re-programmed with the help of the building controls provider.

11. *Train operation and maintenance staff in the use of the energy-metering/performance-tracking system (CxA, O&M)*

During the MBCx process the building operators will be engaged and kept up to speed on issues discovered, gaining valuable insight into the operation of their system. At the end of the process, formal training can occur in the use of the Energy Management System benchmarking and reporting, as well as in the ideal operating conditions of the building systems.

12. *Calculate and report actual building performance (CxA, EMP)*

When the building is determined to be adequately performing and after a full year of operation, the building performance can be calculated as annual energy savings relative to a code reference building. These savings can be normalized to average historical weather data to provide a calculation of the return on investment in building efficiency. Such information will be helpful to building owners for investment in future projects, and to the CaGBC and USGBC to help build the credibility of green and efficient buildings. Consultants too can also gain insight into the performance of their designs. Performance information and deficiencies encountered should be shared so the industry as a whole can learn from shared experience.

MBCx is an involved and comprehensive process that requires diverse expertise. Its particular strength lies in diagnosing large or complex systems by providing clear and immediate references for performance, as well as the tools to identify the cause of performance issues. Efficient designs that make heavy use of building controls to implement energy savings measures are great candidates for an MBCx process. Building owners can have confidence knowing that their building is not only saving energy, but doing so to the full extent that its design will allow, with the appropriate tools in place to maintain performance for the life of the building.

Conclusion

Monitoring-based commissioning is a developing field, with plenty of room for growth and innovation. MBCx demands experience in commissioning, energy modeling, energy auditing, and measurement and verification field in order to integrate this process with building design and construction and to result in optimal building performance.

References

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2. USGBC LEED NC 2012, Second Public Comment Draft, June 2011.