ENERGY MODELING FOR MEASUREMENT AND VERIFICATION

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ABSTRACT

The new LEED-NC version 2.2 requirements incorporate energy modeling which forms the foundation of the measurement and verification process for the Whole Building Calibrated Simulation. As integrated design is adopted by project teams, the energy modeler can play a key role to achieve a successful measurement and verification program. The purpose of this paper is to provide guidelines for using energy modeling as a foundation of measurement and verification as well as using the energy model to shape the controls and operation during the design, construction and operation process.

INTRODUCTION

The intent of measurement and verification is to "provide for the ongoing accountability of building energy consumption over time" per the U.S. Green Building Council Leadership in Energy and Environmental Design (LEED) for New Construction v2.2 Reference Guide -- a powerful idea that takes energy modeling out of the realm of theory and into a real world as a useable tool for a facility manager to achieve true energy efficiency (USGBC, 2005). As a recent summary by the New Buildings Institute comparing actual building performance versus predicted performance shows, there is a wide amount of variability in actual performance and some LEED buildings actually consume more energy than predicted (Fig.1). One of the key findings of this report states: "More feedback is needed from actual building performance results to design phase energy modeling. The current variability between predicted and measured performance has significant implications for the accuracy of the prospective life cycle cost evaluations for any given building. Better feedback to the design community is needed to help calibrate energy modeling results. Follow up investigations into reasons for measured-to-design deviations, and for the wide variations in baseline performance, could improve future modeling and benchmarking" (Turner and Frankel 2008).

Therefore, it is imperative that the owner is empowered with the diagnostic tools to operate the building as intended for the owner to reap the benefits of investing in a high performance building. Likewise, the energy modeler should learn from actual performance data to provide meaningful energy use predictions. Making the connection between energy simulation, a measurement and verification plan, integrated design, and proactive building operation is an important role of the energy modeler. We, as the building simulation community, can greatly influence a successful measurement and verification program and ultimately ensure that the savings predicted in theory occur in reality.

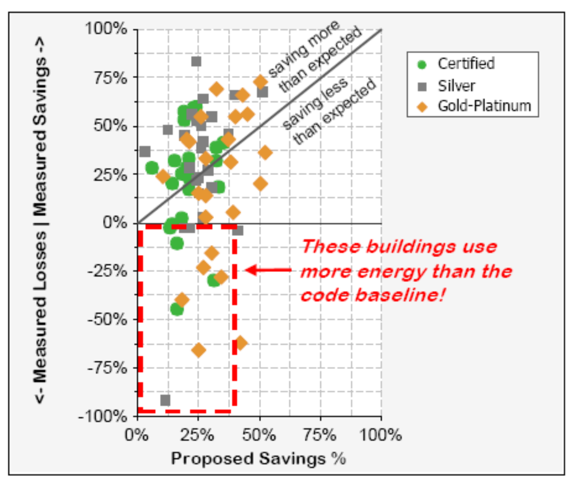

Figure 1: Measured versus Proposed Savings Percentages (Turner, Frankel, 2008)

What many design teams may not realize is that much of the investment to accomplish measurement and verification is already inherent in a new construction project that is using the energy modeling techniques required in ASHRAE Standard 90.1-2004 for LEED Energy and Atmosphere Credit 1, Optimize Energy Performance Option 1 Whole Building Energy Simulation. The output of the energy simulation provides the inputs to the baseline and design case for measurement and verification. Additionally, facilities that pursue sustainable design will already include the majority of the infrastructure needed for measurement and verification. To demonstrate this, an example of a Justice Center complex with a separate Courthouse and Detention Center will be used to illustrate the amount of professional services and measurement and verification infrastructure that was included in the initial project scope.

While these basic elements are inherent to many projects pursuing LEED certification, in order to have an effective measurement and verification program, the energy modeler, owner, engineers, commissioning agent, M&V plan provider, controls contractor, and facility manager must collaborate through the design, construction, and operation process. The energy modeler is well suited to guide the M&V inputs and outputs from early in design since the energy modeler is typically the only design team member that attempts to describe in detail the daily operation of the facility including occupancy patterns, lighting usage, space equipment, HVAC system performance, and the weather.

If the goal of achieving the best facility operation and providing the facility management with diagnostic tools is not enough for an owner to embrace it, additional benefits of M&V programs include:

- allocate costs among programs in a building;
- demonstrate performance of a new technology;
- demonstrate compliance with energy reduction regulations;
- demonstrate compliance with the energy performance requirements of a design contract;
- confirm or calibrate analytical tools; system operation and diagnostics;
- educate students and visitors to a green building;
- earn green building rating points.

A bit of background…the International Performance Measurement and Verification Protocol (IPMVP) was born out of the Energy Savings Performance Contracting industry where the project funding literally is the energy savings. Because performance contracting programs are regularly used by the Federal Government to accomplish important capital projects and to set quality standards among providers, the US DOE Federal Energy Management Program was instrumental in funding the IPMVP. The IPMVP was originally targeted towards existing buildings where the best way to assess how energy is being used before retrofit is to measure it. The challenge of measurement and verification in new construction is addressed by the IPMVP "Concepts and Options for Determining Energy Savings in New Construction" Volume III, Part 1, 2006 where energy savings are calculated by Eq.1:

Equation (1)
Energy savings = Projected Baseline Energy Use – Post-construction Energy Use

Two options from the IPMVP are deemed suitable for the purposes of LEED-NC v2.2 Energy and Atmosphere Credit 5 Measurement and Verification are Option B ECM Isolation and Option D Whole Building Calibrated Simulation. Per the IPMVP, "Option D is most suited to buildings with numerous ECMs that are highly interactive or where building design is integrated and holistic, rendering isolation and M&V of individual ECMs impractical or inappropriate (IPMVP 2006).

This report and presentation focuses on Option D Whole Building Calibrated Simulation. The elements required by Option D are produced with LEED Energy and Atmosphere Credit 1 (EAc1), Optimize Energy Performance, Option 1 Whole Building Energy Simulation. The Proposed Design building performance or design case for LEED EAc1 will be tuned with actual performance data to become the Post-Construction Energy Use in Equation 1. Similarly, the Baseline Design using ASHRAE 90.1-2004 or Title 24 will also be tuned to become the Projected Baseline Energy Use.

Therefore, the initial energy modeling tasks are completed for a project pursing LEED EAc1via Option 1. The fee for energy modeling is included in design fees. An additional fee is required for the professional services to tune the model during the performance period. These fees should be commensurate to the utility cost for the facility, the utility cost risk, and the time period between calibrations.

Next, the capital investment required for measurement and verification will be addressed. The relative amount of energy saved for each end use is important in order to instrument correctly. Per the USGBC LEED for New Construction v2.2 Reference Guide, Chapter 5, “the capital and operational budget for M&V may be established as a percentage or the project’s performance risk over a suitable period of years.” (USGBC, 2005) The energy modeler plays a key role to establish the instrumentation required to describe the significant independent variables that drive energy usage for facility and make these a priority. By defining these meters and control points proactively from the early phases of design, many of energy model inputs and outputs can match tangible facility data through all the tools available per the IPMVP “control / automation systems, security systems, occupant surveys and observations, and specialized sub-metering systems” (IPMVP, 2006).

In order to gather the right data, it is important to know the significant independent variables that drive energy usage for a facility and make these a priority. For instance, if a facility has varied usage, like a courthouse, then actual occupancy information like function start and end time and number of occupants is important. Conversely, if the facility has static occupancy like a detention center, the occupant rates can be assumed to follow a known, fixed pattern.

In order to instrument correctly, it is important to delineate the energy used by process or is uncontrolled by the facility management versus the energy uses that will be controlled and tuned by facility management. For instance, in areas where the lighting is controlled by the occupants, like a courtroom, then the facility manager can control the lighting power but not the time the lights will be on – kW but not kWh. Alternatively, if a facility has daylighting controls, both the kW and kWh can be controlled.

THE TEAM

The process for measurement and verification involves many players at various stages of design, construction, and operation. A typical design process for new construction begins when the Building Owner or Developer first hires an Architect. This Architect hires a design team including often a LEED consultant, an energy modeler, and of course the mechanical and electrical engineers. The engineers need to put the meters in place for long term measurement and verification. The energy modeler needs to recommend energy efficiency improvements over a baseline. The energy modeler should coordinate with the mechanical and electrical engineers on decisions on meters required for long term calibration of energy data. The LEED consultant oversees the process for LEED including the energy modeling and measurement and verification process. During earlier design stages, the Building Owner often hires the Commissioning Agent to oversee that the mechanical and electrical systems are being designed and installed properly. The Commissioning Agent or the Energy Modeler would create the Measurement and Verification Plan which describes sub metering required, setpoints, and accuracy levels of metering equipment. The Measurement and Verification Plan needs to be tied to the mechanical and electrical design. The Facility Manager may be involved in the design stage or may be brought on at the end of construction, though the earlier the better. The Building Owner then hires the General Contractor who hires the Controls Contractor. The Controls Contractor creates the trend logs, monitors the data, and needs to understand the Measurement and Verification Plan to input this plan into the energy management system. The Building Owner typically hires the Facility Manager who is involved with determining if systems are working properly. The Facility Manager should coordinate with the Controls Contractor and the developer of the M&V Plan to understand how to use the energy management system to perform long term trending and fine tuning of building systems. After substantial occupancy, the Energy Modeler, should go back and calibrate the energy model to utility bills, weather, and occupancy trends, for a period of at least one year, and provide the Facility Manager with this energy model to use as a tool for energy management for future building retrofits and long term trending.

THE M&V PROCESS

When installing new M&V systems, especially in new buildings, we wish we had been there in the design phase so we could avoid the physical difficulty and appearance of add on instrumentation. We offer the following methodology for combining measurement and verification requirements for metering and controls during the design, construction and operation process.

During Programming
• Identify the goals of the M&V activities. Consider how systems might serve multiple objectives. Identify obstacles and plans for resolving barriers related to initial cost and continued operation over time. Most of this responsibility will fall on the controls contractor, but will involve all disciplines including electrical and mechanical and even the interior designer regarding the placement and appearance of sensors in a room. • Include all physical infrastructure required for the

M&V program in the building program.

- The owner defines if utility performance will be used to market the facility, how tightly they will control the utility performance risk, the qualifications of the facility management and building engineers, and how much occupants will contribute to the energy performance strategies and what are process loads that are not controlled.
- Project team should determine the scope of the commissioning agent, energy modeler, and M&V process.
- The project team will determine who designs controls. Because the controls contractor is typically the one who executes the building automation and instrumentation, and is hired by the contractor, consider very carefully the controls contractor's prior experience with the implementation of M&V plans and add these requirements to the contractor's selection criteria.
- For the Courthouse and Detention Center project, the City and County of Denver began the development of an RFP for a Commissioning Agent and included M&V in their scope of work.

During Design Development

- Compare the cost of alternative approaches including installing a parallel M&V system, piggy-backing on the building IT and EMCS systems, or outsourcing it all to an applications service provider. Design of the M&V system will be according to what achieves the goals set for the system in the programming phase. Design will entail: Hardware; Software; Data Collection; Communication & Management; Procedures; and most importantly: People. Ultimately, it is people that will act on the information. So identifying who those people are, asking them what they need, and involving them in the design of the M&V system is critical. Decide on the platform upon which to build a specific solution in Construction Documents.
- The architectural, engineering team, and energy modeler will develop detailed strategies for saving energy over the baseline. EAc1 Table 1.4 Comparison.
- Energy modeler can determine the performance risk of each, independent and dependent variables, and sensitivity.
- Use ASHRAE Guideline 14-2002, *Measurement of Energy and Demand Savings* to define the appropriate margin of error.
- Decide on weather data for normalization strategy
- The team will have an understanding of what type of instrumentation is typical to the equipment. being selected. Gaps between the energy savings by end use and the amount of data and control will indicate the need for additional instrumentation.
- Free instrumentation – occupied times, set point temperatures, fan schedules, air volumes, fan and pump kW, chiller kW, chiller operating times. Might be free – outdoor air delivery monitoring (EQc1), electric meter kW and kWh for whole building, gas meter for whole building, chiller tonnage, boiler firing rates. Might require investment – DX cooling, chilled water flow rates, chiller kW/ton, hot water flow rates, lighting kW and kWh, receptacle load kW and kWh, process equipment.
- Estimate costs for instrumentation, M&V professional services during design and construction, and M&V professional services during the performance period.
- The Detention Center and Courthouse were provided with a list of control points and meters that will be required for measurement and verification by the commissioning agent. Energy modeling was performed to examine life cycle cost of system options and compared the current design to the baseline model.

During Construction Documents

- Specify the details of required meters, instruments, transducers and signal conditioning, communications equipment, data storage, workstations, and supporting equipment such as displays in the lobby or dedicated outputs. Show placement of instruments on drawings and runs of instrumentation wire and conduit. Include complete M&V system diagram with all points.
- Write the M&V plan including the desired output reports for the building automation system. Make the M&V plan integrated into the facility management process and utility budget process for the owner. Duties for collection of data that is outside the building automation system (like an event schedule) should be assigned.
- Loss of the measurement and verification data can be a real problem so make building automation be robust. Define frequency that data will be permanently stored and how to make it fail safe. During the value engineering process for the Detention Center and Courthouse the project teams were informed by the commissioning agent which meters needed to stay in the scope of work in order to complete the M&V process. Drawings and specs were reviewed during design phase intervals for required meters and control points. And the M&V plan was developed.

During Construction

- Controls contractor and commissioning agent to commission the M&V system, sub-metering, and the report functions for M&V.
- Commissioning agent or energy modeler to visit the construction site to verify installation and operation of energy efficiency strategies.
- Provide functional testing with short term monitoring of daylighting, occupancy control, etc.
- Calibrate the energy model based on as-built conditions.
- There may not be real data since the building is not occupied but the points and information should be coherent.
- The energy model will be calibrated for the Detention Center and Courthouse based on as-built conditions. The mechanical and electrical submittals were reviewed for required meters. Functional testing will be performed by the commissioning agent.

At Occupancy

- Provide the facility staff with a User's Manual. Staff at the building will turn over with time and a complete manual chained to the M&V workstation will enable the owner to continue to get good results from the M&V system. The manual should include a complete inventory of all the parts of the system including make and model number for replacement, a diagram of the physical location of each part and the physiology of how those parts work together, instructions for any routine services such as back-up and archiving of data, how to generate reports of actionable data, management of alarms and key parameters used for ongoing commissioning or diagnostics. Lists of who needs to get each type of report. Lists of any changes made to the system or feedback from customers getting the reports.

The M&V Period

- Starts after the building has achieved a reasonable degree of occupancy and stability.
- The facility manager pulls data from building automation system and other sources (for hours of occupancy, occupants, event, etc.)
- The commissioning agent assists the facility operations to pull data from building automation and performs QC of the data.

  Do a quick eyeball of the utility bill, measured data, and the Projected Baseline Energy Use – Post-construction Energy Use prior to adjustments and the facility manager immediately begins to tune the equipment performance.

The Calibrated Simulation

- After substantial occupancy, calibrate the energy model to the building with at least one year of data.
  - As-built and baseline simulation (IPMVP 4.5.7)
  - Method 1 / Method 2 (IPMVP 4.5.7)
  - Discussion of errors IPMVP 4.5.8 and how to minimize them / plan for them
  - The model will be changed to incorporate measured data – actual schedules, lighting kW, custom part load curves, etc.
  - Normalizing weather
  - Compare to original EAc1 savings prediction.
- The sign of an effective M&V plan is that it is a tool for the facility manager to diagnose problems and pro-actively write work orders. Close collaboration between the energy modeler, commissioning agent, controls contractor, and facility management staff will be required for this tool to be useful for long term building fine tuning and retrofit savings predictions.


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Figure 2: A deserted unused computer is a sign of a poor M&V plan.

- For example, the Courthouse and Detention Center will be provided with bi-monthly calibration including all of these parameters with several meetings between all players to discuss the changes to the building compared to the original model and how to use the model for building fine tuning and retrofit estimates.

FINANCIAL IMPACT

Costs for measurement and verification vary significantly and depend on several factors including the full scope of services for the consultant performing the M&V, the size of the project, the type of building, the number of metered systems, the IPMVP Option selected, and more. One study on renewable energy in the IPMVP suggests a rule of thumb for M&V of 4% to 10% of the typical project cost savings based on IPMVP Option B (Walker, et al 1999). In another study by Davis Langdon, cost for the meters for measurement and verification can add $2 to $4 per square foot to the cost of a project. In addition, the cost of the studies can range from $50,000 to $200,000 (Morris and Matthiessen 2008). The costs for measurement and verification for the Detention Center and Courthouse example falls within the range of what this Davis Langdon study suggests.

CONCLUSION

Who benefits from measurement and verification? The owner for better performance, the facility manager with troubleshooting tools, the energy modeler for more accurate model, as well as the design team for proof of concept. Since energy modeling is typically done early in design development, there is time to influence projects to pursue M&V. The simulation and new building systems already account for a portion of the investment so why not fully invest in M&V, get a well tuned building and get the simulation to work for the client out of the realm of theory and into day to day practice. It's time building owners learn how to take this simple step to really get their money's worth.

This paper attempts to clearly break down the full ideal measurement and verification process so that the owner, controls contractor, facility manager, contractor, designer, engineer, commissioning agent, energy engineer, and more can better understand how all the pieces and parts of this multi-disciplinary task fit together to obtain a fully optimized fine tuned building.

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