Technical vs. Process Commissioning

Measurement And Verification

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The purpose of this article series has been to present the technical commissioning process for new building commissioning. We began by outlining the owner's expectations in the Owners Project Requirements (OPR) document. Next, we described the Basis of Design (BOD) document, which ensures that the project designers meet the requirements spelled out in the OPR document.

If we were moving through an actual project in sequence with these articles, by this point we would also have created the commissioning plan (CP), which outlines the commissioning-related tasks that everyone involved in the project must complete to make sure the objectives set forth in the OPR document are achieved. We also would have been carefully monitoring the construction process and overseeing all prefunctional testing (PFT) to ensure that all equipment and systems have been properly installed—and can be properly started and run. By now, too, we would have directed and verified the completion of all functional performance testing (FPT), so we would know that all building systems and components are working properly under real-world scenarios. Finally, we would have supervised the training of the owner's staff in correct building operation and maintenance procedures.

This article explains the next-to-last step in the technical commissioning process: measurement and verification (M&V). Practically speaking, M&V involves using industry-standard tools and processes to check and ensure that the now-occupied facilities (whether a single building or a group of structures) perform at the owner's expected level of resource efficiency—and what steps you can take if the desired performance level has not been achieved.

Sometimes Things Go Wrong

In the best-case scenario, a building is designed, constructed, and commissioned to function in conformance

This is the eighth in a series of bimonthly articles that explain the technical commissioning process for new buildings. Some of these articles' content is based on *ASHRAE Guideline 0-2005, The Commissioning Process* (published 2005) and the National Environmental Balancing Bureau (NEBB) publication *Procedural Standards for Whole Building Systems Technical Commissioning for New Construction* (revised April 2013). In addition, some of the information in this article series has been adapted from an unpublished NEBB standard titled *NEBB Standard Owner's Project Requirements (OPR) Guideline* (draft dated June 20, 2011); and from NEBB's *Procedural Standards for Building Enclosure Testing* (March 2013).

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TABLE 1 Four M&V plan options. (The information in Table 1 is based on *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings, Volume 1* (September 2010; Efficiency Valuation Organization, Washington, D.C.); pp. 21 – 22.

M&V PLAN OPTION	HOW SAVINGS ARE DETERMINED	COMMON APPLICATIONS
A. RETROFIT ISOLATION: MEASURING KEY PARAMETERS Energy consumption is determined by field measurement of selected parameters: Specifically, those that define the energy use of the building's energy conservation measures (ECMs) and/or the success of the project. Short-term or continuous measurement. Parameters not measured are estimated.	Calculated by measuring baseline and selected parameters; and estimated values. Routine/non-routine adjustments as needed.	A lighting retrofit (power draw is the key measured performance parameter). Estimate operating hours for lights based on building schedules and occupant behavior.
B. RETROFIT ISOLATION: MEASURING ALL PARAMETERS Consumption is determined by field measurement of the energy use of the building's ECM-affected system. Short-term or continuous measurement.	Calculated by measuring baseline and selected parameters; and/or proxies of energy use. Routine/non-routine adjustments as needed.	Application of a variable-speed drive and motor controls to adjust pump flow. Measure power every minute with a kW meter installed on the motor's electrical supply. During the baseline period, leave the meter in place for a week to determine constant loads. Then leave the meter in place during the performance-testing period to identify and track usage variations.
C. MEASURING THE ENTIRE BUILDING Consumption is determined by measuring energy use at the whole building or sub-building level. Continuous measurement.	Calculated by measuring whole-building baseline and utility-meter data. Routine adjustments as needed, using techniques such as simple comparison or regression analysis. Non-routine adjustments as needed.	A multifaceted energy-management program affecting many of a building's systems. Measure energy use by monitoring utility meters for a 12-month baseline period and then throughout the performance-testing period.
D CALIBRATED SIMULATION Consumption is determined by simulating the energy use of the whole building or a sub-facility. Simulation routines must adequately model actual energy use. Performance is measured in the facility. *Note:* This option requires considerable skill in developing calibrated simulations.	Calculated from simulated energy use; calibrated with hourly or monthly utility-billing data. End-use metering may be employed to help refine input data.	Multifaceted energy management program that lacks a metered baseline but affects many systems in a facility.

with the OPR. The owner then takes occupancy of the building, uses it as it was designed to be used, and enjoys a building that performs within a reasonably acceptable range of its OPR parameters. In that case, the M&V process is little more than an academic exercise that measures and verifies the as-expected outcome of an effective commissioning process.

Under less-than-ideal conditions, however, the building owner might be getting power bills that are 25% higher than was specified in the OPR. In that case, you can use the M&V process to carefully analyze the building's energy consumption, find out where the problems lie, and then help the owner understand the reasons for the building's unexpected performance. For example, if the owner decides to operate an entire second shift in a building designed for only a first shift, the facility's resource consumption will be dramatically higher than the energy model you specified in the OPR document.

And then there are buildings with major issues.

There are a thousand and one reasons why things go wrong—and buildings are just as likely to "suffer the slings and arrows of outrageous fortune" as anything created by man. Whether it is the result of planning, design, construction, or even commissioning problems, we sometimes end up with underperforming buildings that require constant adjustment and recalibration after the facilities are occupied. We find ourselves asking, "What went wrong? Were our OPR requirements inaccurate? Have unresolved or unknown design or construction challenges caused higher-than-expected resource consumption? Or is the building being occupied and operated beyond the parameters specified in the OPR document?"

This article is intended to help you deal with problem projects that can make your life miserable.

Vital Importance of Metering and Submetering

The saying "You can't manage what you don't measure" is especially true when you are struggling to control a building's energy costs. Certainly, metering the building's total utility usage is a given. But the ability to submeter various loads cannot be overemphasized. It's the practice of submetering that enables you to accurately determine how the building's energy is actually being used—or wasted. A well-designed submetering system also provides an infrastructure that enables you to effectively manage energy consumption by system type, which makes it easier to pinpoint and deal with problem areas.

The three general categories of electrical loads to submeter are: the central HVAC plant; lighting; and plug loads.

A facility's level of submetering plays a key role in how you develop and execute your M&V plan. Hopefully, when you developed the OPR document with the owner, you were able to design into the building an effective level of submetering. But what if you came into the project late, and you realize as you start M&V that the building has limited submetering capabilities? In that case, you will need to investigate to determine which loads can actually be submetered.

The layout and design of the building's electrical system will determine the feasibility of installing submeters. Under a best-case scenario, individual feeders are installed for each of the main categories (HVAC, lighting, and plug loads). The cost of submetering has significantly decreased in recent years, so it may be that retrofitting submeters is an option. Submetering can be a combination of utility meters and power meters that are connected to the building automation system (BAS).

Developing Your M&V Plan

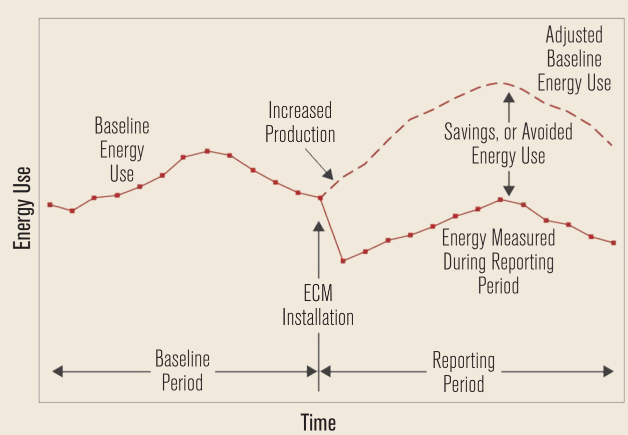
You need a workable plan to understand, adjust, and verify a building's energy performance. Fortunately, you do not have to start from scratch.

We consider the September 2010 edition of the *International Performance Measurement and Verification Protocol* (or IPMVP) to be an excellent reference resource for developing an M&V plan. IPMVP describes four plan options, which gives you the ability to develop a customized M&V plan that best matches your building's needs.

While it is beyond the scope of this article to describe the details of all four M&V plan options, a brief overview of each one is presented in *Table 1*. To determine whole-building energy use at the metered level, Option C is the preferred approach.

Note that *Table 1* contains several references to "routine" and "non-routine" adjustments. That is an important consideration, because your M&V plan must factor in a wide range of variables that can change between the baseline period (typically one year) and the metered performance-testing period (also typically one year). Simply comparing energy bills without factoring in your key

FIGURE 1 Sample energy-consumption tracking to determine savings (aka, avoided energy use). (Information in Figure 2 based on *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings, Volume 1*, p. 12.)



variables will yield an inaccurate analysis of a building's energy usage. Weather seasons, hours of operation, occupant loads and behaviors, setpoint adjustments, and more must all be well-documented and carefully accounted for during both the baseline and the test periods.

Measuring Avoided Energy Use

Energy costs keep rising, and building owners do not want to pay any more than they absolutely must to operate their facilities. So whether you talk about reducing consumption through "savings" or through "avoided energy," your building owner wants to know more.

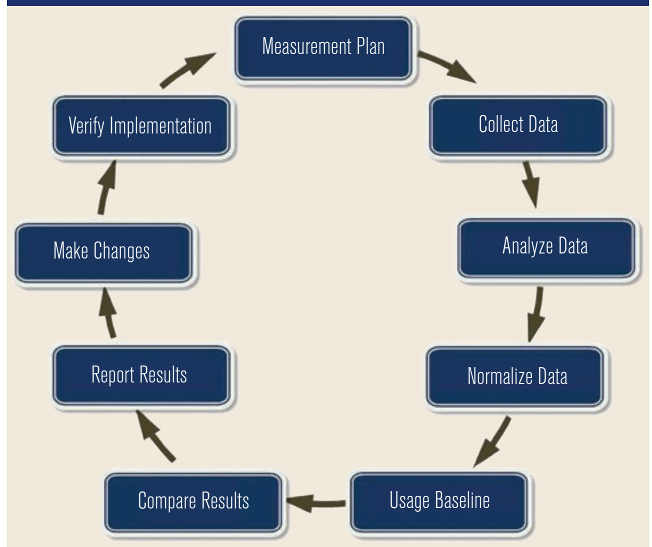
Figure 1 presents a sample energy-use history for an industrial boiler before and after the addition of an energy conservation measure (ECM) to recover flue-gas heat. However, at about the same time the ECM was installed, plant production increased.

To properly document the ECM's impact, its energy effect must be separated from that of the increased production. Baseline energy use (before ECM installation) was studied to determine the relationship between energy use and production levels. After ECM installation, the baseline data was used to estimate how much energy the plant *would have used* each month if there had been no ECM ("adjusted baseline energy"). The savings, or "avoided energy use" is the difference between the adjusted baseline energy and the energy that was actually used during the reporting period.

Without adjusting for the production increase, the difference between the baseline and the reporting-period data would have been much less, thus effectively undervaluing the benefit of the ECM.[1]

While this particular example involves a retrofit to an existing facility, the same type of analysis must be completed when comparing predicted the energy use of a new building to its actual use.

FIGURE 2 Overview of ASHRAE's PMP process. (Source: *Performance Measurement Protocols for Commercial Buildings: Best Practices Guide*); p. 5.



Calculating Energy Savings

When you are working to adjust the performance of a problem building, at some point you will need to explain to the owner exactly how much is being saved as a result of whatever ECMs the owner has authorized. That's where ASHRAE Guideline 14-2002, *Measurement of Energy and Demand Savings* comes in.

Guideline 14-2002 provides a standardized, step-by-step method for calculating the energy savings gained from building improvements. You can use Guideline 14-2002 to:

- Establish minimum acceptable levels of building performance.
- Measure and use baseline and post-improvement testing data to determine energy savings.
- (Where applicable) calculate energy- and demand-savings payments to energy service companies (ESCOs),

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utilities, or other energy-conservation providers that may rely on energy savings as a basis for repaying improvement costs.[2]

Verifying Superior Building Performance

At this point you may be asking, "Apart from whatever performance goals were established in the OPR document, how can we know what sort of building-performance objectives to shoot for? How can we really determine if our M&V adjustments have truly created a 'high-performance' building?"

The answers can be found in ASHRAE's *Performance Measurement Protocols for Commercial Buildings: Best Practices Guide*, or PMP. PMP (*Figure 2,* Page 35) provides a standardized and consistent set of "best-practice" protocols you can use to evaluate and improve the performance of a commercial building throughout its service life.

PMP identifies what to measure, how to measure it, and how often to measure it. For each of the six measurement categories (energy, water, thermal comfort, indoor air quality, lighting/daylighting, and acoustics), step-by-step protocols are provided at three levels of cost and accuracy: low, medium and high—which gives you a range of approaches to choose from, depending on the level of effort and intensity that should characterize your building's M&V plan:

Basic Evaluation (low cost/accuracy) is a basic approach that uses observations of building characteristics, occupant perceptions, and utility-bill data to quantify performance.

Diagnostic Measurement (medium cost/accuracy) is an intermediate diagnostic methodology that uses measurements to diagnose baseline problems and track performance against industry standards.

Advanced Analysis (high cost/accuracy) uses the results of the first two levels—plus the results of professional investigative processes—to quantify performance and identify specific improvement actions.[3]

Other Tools Are Available

Depending on the owner's needs and desires, there are other tools you can use to measure and track a building's resource consumption, including:

Building Energy Quotient (bEQ). ASHRAE's Building Energy Quotient (bEQ) is a building-energy rating program that provides information about a building's energy use, indoor air quality (IAQ), and occupant comfort. The program is based on ASHRAE standards and methodologies, and can only be administered by licensed professional engineers or ASHRAE-certified professionals. Qualified practitioners can use the bEQ process to compare a building's performance with similar building types. Buildings within an owner's real estate portfolio can be compared against each other and reevaluated over time to see if improvements deliver the expected levels of performance—which can help owners maximize their building investments.

Energy Star Portfolio Manager. The Environmental Protection Agency's Energy Star Portfolio Manager is a secure, online tool that can help you establish a building's baseline of energy and water consumption—as well as its greenhouse gas emission levels. The tool rates a building's energy performance on a scale of 1 to 100 relative to similar buildings nationwide with respect to climate, building use, building size, and occupancy; and can be used to benchmark the performance of one facility or a portfolio of buildings. According the EPA's website, 40% of all the commercial buildings in the United States have already been benchmarked using Portfolio Manager.

Multiple Paths to One Objective

Hopefully, your project was planned, designed, constructed, and technically commissioned in such a way that the owner is happy. In that case, your M&V process will be satisfying and rewarding for both you and the owner.

But what if the building isn't performing as expected? You'll need a thorough M&V process to discover—and explain to the owner—the reasons for the delta between the OPR and the building's actual performance.

And finally, what if the building is a Pandora's Box of problems, issues, and unfulfilled performance expectations? Hopefully, some of the strategies and resources described in this article will be of value to you.

Since the final outcome of the technical commissioning process is a satisfied owner, the commissioning agent (CxA) must work closely with the owner to understand his or her objectives, priorities, desires, and budget constraints. And be sure to remember that all successful M&V processes *start* and *end* with accurate measurements.

With M&V, there is no magic formula; no "one size fits all" approach—and there's more than one "road home." From a pure cost-effectiveness standpoint—and if energy performance from a "total building" perspective is the goal—the Energy Star Portfolio Manager can play a major role in your M&V process. Of course, if energy performance is clearly on the decline (or already down the tubes) it will take a much deeper analysis to identify and alleviate the problems.

But Wait, There's More

Our original idea was for this eight-part overview of the technical commissioning process to be complete at this point. But after careful consideration, we've decided to turn our planned *eight* articles into *nine*. So our next, truly final article in this series will cover the topic of **ongoing commissioning** (OCx).

OCx has become increasing valued in the last decade, and it is an important final step that we encourage you to build into your overall Cx plans. The simple fact is that building conditions *will change* after you complete the M&V process; the only questions are: "How much?" and "How soon?" After all, equipment deteriorates, systems break, settings wander (or are purposefully modified), occupant loads change, maintenance staff comes and goes, and performance deteriorates. But owners still desire high-performing buildings regardless of how many years have passed since construction was completed; hence the need for OCx.

The good news is that OCx offers solid performance and efficiency benefits, including a potential three-point "boost" toward LEED certification. According to the website of the U.S. Green Building Council, the purpose of OCx is to proactively use the "building commissioning process to improve building operations, energy, and resource efficiency" on a continuing basis over the building's life, including "planning, point monitoring, system testing, performance verification, corrective action response, ongoing measurement, and documentation."[4]

So join us here in October for the conclusion to our overview of the technical commissioning process.

References

1. U.S. Department of Energy. *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings, Volume 1*, p. 12.

2. ASHRAE Guideline 14-2002, *Measurement of Energy and Demand Savings*, p. 4.

3. ASHRAE. 2013. *Performance Measurement Protocols for Commercial Buildings: Best Practices Guide*, p. xv-xvi.

4. USGBC. 2013. LEED O+M: Existing Buildings v4, Ongoing commissioning, http://tinyurl.com/ml43gx8. ■