

MEASUREMENT AND VERIFICATION OF ENERGY SAVINGS



Issue Brief

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How technology can change the game and encourage more growth in building energy efficiency markets, domestically and worldwide.

INTRODUCTION

This is the second in a series of briefs exploring how technology, data and information are used to improve building energy efficiency. The first brief looked at the technologies used in high-performance buildings and the value of building performance information to decision-makers. In this brief, we focus on the measurement and verification (M&V) of energy savings. We review the state of the industry and identify current trends in industry governance and the application of technology to current practices.

The business of building energy efficiency continues to grow at an amazing pace.¹ Pressures exerted by expanding international economies and concerns with energy supplies and global climate change are likely to continue feeding this growth trend. To meet this demand, the energy efficiency industry needs to grow and adapt appropriately. The industry must continue to educate building owners, managers and tenants about their buildings. This must include management strategies and performance metrics, accompanied by an appropriate level of governance, to promote owners' trust and confidence in the value of efficiency improvements. The industry needs to attract, develop and retain a workforce skilled in energy efficiency, and use technology and communications to leverage that workforce.

Technology has dramatically changed the financial, medical and automotive industries; and it is starting to transform the energy efficiency industry. The application of information technologies to M&V could radically improve current practices. Significant cost reductions through automation are possible, especially if M&V is integrated with energy information, performance monitoring, and fault detection and diagnostics. Advanced analytics provide for improved accuracy, increased confidence in the results, and enhanced decision support.

UNDERSTANDING PERFORMANCE: MEASUREMENT AND VERIFICATION TODAY

Understanding building performance is a central theme among building owners and managers. Measurement and verification (M&V) of savings from energy efficiency projects has evolved into a well-defined and mature discipline in North America. There are guidelines and protocols that define M&V, and a certification path is available for the professionals who practice it. The primary purpose of M&V is to validate that time, effort and money invested to reduce energy usage in buildings provides the expected results. This is done by accurately measuring (or estimating) the savings generated from any type of energy efficiency project, including major renovations, retrofits, facility improvements, and operational and behavioral changes. These projects can be implemented solely by a building owner or through outside parties, such as energy service providers, equipment manufacturers, financial service providers and utilities.

¹ Karen Ehrhardt-Martinez and Skip Laitner, ACEEE, "The Size of the U.S. Energy Efficiency Market," May 2008.

M&V is a common component of energy-related government incentive and education programs, utility rebate programs, and contractual arrangements between two or more parties involved with the delivery of energy efficiency projects with savings guarantees – arrangements often referred to as energy savings performance contracting. In many cases M&V directly affects financial payments between the parties involved.

The following table summarizes the four general M&V approaches regularly applied today. It is common for multiple approaches to be applied to an individual energy efficiency project, and in some cases hybrid approaches are created. The industry allows for significant flexibility in the design of M&V plans to fit the scope and objectives of each project.

Common Name	Description	Example	IPMVP* Option
Retrofit Isolation Approach – Key Parameter Measurement	Savings calculated for a single measure; key parameters measured; some parameters estimated; one-time or ongoing measurements made	Replacing T12 lamps and magnetic ballasts with T8 lamps and electronic ballasts. Savings are the number of lamps/ballasts installed, times the measured wattage difference between the original and new lamps/ballasts, times an agreed-upon estimate of operating hours per year.	A
Retrofit Isolation Approach – All Parameter Measurement	Savings calculated for a single measure; all parameters measured; one-time or ongoing measurements made	Changing the operating schedule on an air-handler. Savings are the air-handler fan’s wattage, measured once or continuously, times the difference in run-hours measured before and after the schedule change.	B
Whole-Facility or Meter Approach	Net savings calculated for all measures; regression model used to create a baseline; ongoing energy usage measured	Installing a bundle of energy efficiency improvements to the building envelope, HVAC and lighting systems. Savings are the difference between actual utility bills before after the retrofit, adjusted based on modeling of actual weather data for the same billing periods.	C
Calibrated Simulation Approach	Savings calculated for both individual measures and net of all measures; building modeling software used to predict energy usage with and without measures	Incorporating energy efficiency into the design of a new building. Calibrated simulation models are used to determine savings.	D

*Note: The International Performance Measurement and Verification Protocol (IPMVP) is the most commonly used M&V reference document in the industry. See the section on governance for a further description.

M&V used for validating government incentive programs and utility rebate programs often apply short-term measurements using retrofit isolation approaches. These are quick and inexpensive approaches designed to prove that a retrofit or other measure has the potential to save energy. Although this type of measurement and verification does not ensure the achievement of long-term savings, it helps to ensure that measures are properly installed and are performing as expected.

For projects involving contractual arrangements between multiple parties, a variety and blend of M&V approaches are regularly practiced. M&V plans are carefully defined in contracts with terms lasting 20 years or longer. However, there is a trend toward shorter-term or one-time measurements, similar to those used in government and utility programs. There has also been a trend toward option-A retrofit isolation approaches, where some factors are estimated instead of being measured. Estimated values made in M&V calculations are sometimes referred to as stipulations. For example, utility rates and the operating hours of lighting systems are often stipulated.

It is important to design the M&V plan based on the goals and makeup of the energy efficiency project. The trend toward retrofit isolation approaches (Options A and B) means that the M&V plans created are dependent on the energy efficiency measures: For the most part, a custom plan is created for each project.

FOCUSING ON GOVERNANCE: CREATING TRANSPARENT, COMMON APPROACHES AND TOOLS

Governance for a business or industry is the set of processes, customs, policies, laws, and institutions that affect the way business is performed. For the energy efficiency industry this includes the development and maintenance of education materials, standards, and certification programs. M&V is intended to provide confidence that the technologies deployed and features implemented in buildings are improving performance and creating the desired outcomes.

Numerous guidelines and protocols have been written around M&V. The following three pieces are foundational: Almost every M&V-related document references one or more of them.

1. International Performance Measurement and Verification Protocol (IPMVP)²

This protocol, maintained by the non-profit Efficiency Valuation Organization (EVO) (latest version released in September 2010), is the single most recognized M&V guide or standard in the industry – the EVO website claims it is used in more than 40 countries. The protocol allows for substantial flexibility and promotes the implementation of M&V by certified experts.

2. ASHRAE Guideline 14 – 2002 Measurement of Energy and Demand Savings³

This guideline was developed by ASHRAE. It is one of the more technical M&V documents and is referenced by IPMVP and most other M&V documents. Although the guideline states that it will be updated on a five-year cycle, there have been no updates since its release in 2002.

3. M&V Guidelines: Measurement and Verification of Federal Energy Projects (FEMP)⁴

This document was prepared for the U.S. Department of Energy (DOE) Federal Energy Management Program (FEMP). It is often referred to as the FEMP M&V Guidelines, and it closely follows the IPMVP. This guideline defines unique reporting requirements for Energy Service Companies (ESCOs) working with the federal government on energy savings performance contracts (ESPCs).

² Efficiency Valuation Organization (EVO). International Performance Measurement and Verification Protocol (IPMVP) Public Library of Documents, http://www.evo-world.org/index.php?option=com_content&task=view&id=272&Itemid=279.

³ ASHRAE 2002. ASHRAE Guideline 14-2002 for Measurement of Energy and Demand Savings, American Society of Heating, Refrigeration and Air Conditioning Engineers, Atlanta, GA.

⁴ U.S. Department of Energy Federal Energy Management Program. M&V Guidelines: Measurement and Verification for Federal Energy Projects Version 3.0, http://www1.eere.energy.gov/femp/pdfs/mv_guidelines.pdf.

Although these documents have served the industry well, there has been little work to extend the classic M&V approaches and apply modern information technologies and analytics. Changes driven by technology are creating a need for new and updated education materials, standards and certification programs.

Today, the most established certification program for M&V practitioners is the Certified Measurement and Verification Professional (CMVP) program developed by the Association of Energy Engineers (AEE), in cooperation with the EVO. AEE provides training and administers testing as part of the certification. The training is based almost exclusively on the IPMVP, and applicants must meet experience requirements in energy, building management, or M&V. The CMVP has been available since 1981, and there are now more than 15,000 certified professionals globally.

Beyond the certification for industry professionals, there are no certification paths for M&V software, approaches, plans, or project results. There are also no M&V standards currently developed by national or international standards organizations, although the IPMVP is often treated as one. With technology staged to change the business of building efficiency, the industry needs to adapt accordingly. The following three initiatives may lead to the development and adoption of additional standards and certification programs.

1. National Evaluation, Measurement and Verification Standard

DOE is researching the possibility of a new national standard that would cover traditional M&V as well as the evaluation of federal, state and utility energy efficiency programs. DOE funded a scoping study and report⁵ stating three reasons to create a national standard:

- a. Streamline and reduce the cost of M&V and improve comparability of results
- b. Support the U.S. EPA's potential adoption of energy efficiency as the most effective technology for controlling air quality
- c. Support potential federal legislation to create a national energy resource standard that includes energy efficiency

⁵ U.S. Department of Energy. National Energy Efficiency Evaluation, Measurement and Verification (EM&V) Standard: Scoping Study of Issues and Implementation Requirements, April 2011.

2. ISO 50001 – Energy Management Systems – Requirements with Guidance for Use⁶

This new ISO standard, released in 2011, is intended to help organizations create a management structure and systematic approach to achieve continual improvements in energy management and efficiency efforts. There are private companies qualified to provide certification to this standard.

⁶ International Organization for Standardization. ISO 50001:2011 Energy Management Systems – Requirements with Guidance for Use.

3. Superior Energy Performance Certification Program (SEP)

The SEP program is being developed by the U.S. Council for Energy-Efficient Manufacturing, including the DOE, the EPA, and the U.S. Department of Commerce. A central part of the program is the new global energy management standard, ISO 50001. SEP includes a certification path for companies adopting the standard, and the American National Standards Institute (ANSI) provides an accreditation program for certifying agents. The SEP is scheduled for a U.S. launch in 2012. Although the SEP program is focused on industrial facilities, it could easily be extended to commercial buildings.

THE PROMISE OF TECHNOLOGY-ENABLED M&V

Technology has transformed other industries and has tremendous potential in the built environment. For example, 20 years ago a typical automobile had five sensors on board, while today an average automobile today has over 200 sensors and up to 50 computers or microprocessors⁷ that continuously monitor and control engine performance and other functions. Technology further enables automated engine diagnostics and services such as OnStar, where data is transmitted to data centers and is used by experts for further review and analysis.

Similar changes can be seen in the financial and medical fields. The majority of stock trades on the New York Stock Exchange are executed automatically, using computers with advanced software to mine large amounts of data, run sophisticated analytics, and log billions of transactions. In the medical field, patient records and information are quickly and securely shared between medical facilities, doctors, pharmacists and other service providers. It is now common for an x-ray taken in an emergency room to be reviewed by a highly skilled physician located hundreds of miles away.

Technology is changing the building energy efficiency industry in similar ways. Some of the changes have been evolving for years, while others are just emerging. The effects of technology can be seen in all aspects of the built environment and the energy efficiency business.

- **Technology lowers M&V costs.** In the energy efficiency industry, M&V is not always considered favorably, as it is thought to be an added expense that reduces both the funding available for energy efficiency measures and the project's return on investment. Historically, M&V costs have been as much as 10 percent of total project costs, but in the past 10 to 15 years these costs have been decreasing and are now typically less than 5 percent. Automation and analytics are expected to drive M&V costs to below 2 percent, while maintaining or improving accuracy and quality. Integrating M&V with performance monitoring, commissioning, fault detection and diagnostics, and energy information leverages the required technology investments and increases the overall benefits derived from building data.
- **Advances in electric power meters spur deployment.** Electric power meters have evolved significantly over the last 15 years with ever-increasing capabilities at lower costs. These meters can hold significantly more data, provide event-triggered high-resolution data capture, automatically detect anomalous energy usage, and easily integrate with building information systems. Further advancements are enabling smart meters for the smart utility grid by adding two-way communication capability between the utility and building. The reduction in metering costs has resulted in significantly more sub-metering by building owners, allowing them to better understand and manage energy usage.
- **Building sensors provide better diagnostics.** Advanced building sensors,⁸ although lagging behind power meters in market readiness, are likely to explode within the next decade or two. Where buildings today have hundreds to thousands of sensors, the building of the future will have millions. These sensors will dramatically affect both building controls and building information systems. Many of today's buildings have more than enough sensors to support advanced diagnostics and M&V.

⁷ "Motoring with microprocessors," Jim Turley, www.eetimes.com, 8/11/2003.

⁸ Sensors include a wide array of devices currently used in buildings to measure temperatures, pressures, flow rates, power, and other traditional values, and future sensors that will measure room occupancy counts, occupant activity levels, light intensities on every work surface, and plug loads at every receptacle.

- **Increased connectivity with business systems expands available data.** Technology allows for the easy integration of multiple building systems and other business applications: This is referred to as connectivity. Smarter devices, broader networks, standard communication protocols, and IT convergence all lead to better connectivity and the sharing of data and information. Connectivity provides new and expanded data sources for M&V. Besides weather, the next biggest driver of energy usage in buildings is typically occupancy. Reliable occupancy information historically has been difficult to come by. Connectivity allows for occupancy and occupancy-related factors – such as the number of hospital beds filled, the number of hotel guests, and the amount of rented tenant space – to be automatically pulled from security and business databases.
- **Data availability offers new levels of analysis.** The use of new meters, sensors and connectivity in buildings simply means more data available for M&V. In electric meters, for example, trend or interval energy usage data is now commonly recorded at 15- or even one-minute sample intervals. Where M&V was once based on 12 monthly utility bills derived from a single utility meter, there are now multiple sub-meters, each with 8,760 or more data points per year. That is 1,000 to 10,000 times more meter data.
- **Automation and built-in analytics extract key performance information.** While technology tends to create an overwhelming amount of data, it also provides the tools to manage it. Modern buildings are data-rich environments, ideal for the application of advanced analytics. The application of descriptive and inferential statistics to M&V allows for simplification, automation and ultimately reduced M&V costs, while at the same time increasing the amount of information that can be extracted from the data, and increasing accuracy and confidence in the results.
- **Advanced analytics track whole-buildings and technology interactions.** As energy efficiency goals become more aggressive, energy efficiency projects become larger and the number of different measures in a typical project increases. This increases the chance that the measures will interact with each other and affect the overall savings. Accounting for all interactions can quickly become complicated, and in practice today, some interactions are simply ignored. An automated whole-facility M&V approach is a simple way to properly handle interactions between efficiency measures.
- **Changes in building use are identified and analyzed:** A big challenge for M&V is properly addressing changes in building use that affect energy usage. It is important to identify these changes promptly and handle them properly. Examples include changing building occupancy; changing the space type (such as from storage space to office space); adding a wing, floor or other square footage; expanding regular operating hours into the evening or weekend; and installing or removing energy-consuming equipment. In these cases, especially with the whole-facility M&V approach, adjustments are made to account for building use changes before the savings are calculated. However, identifying the changes and estimating the adjustments can be difficult. Using advanced, statistical-based analytics with an ongoing stream of energy usage data, these changes can be automatically detected within days or months of the change. Furthermore, the magnitude of the energy impact from the change can be automatically estimated with a high level of statistical confidence. Automating the processes for identifying building use changes and calculating the impact of these changes dramatically reduces M&V costs.

- **Persistence of savings from efficiency investments is documented.** A challenge with every energy efficiency project is to maintain the savings over long periods. This normally requires continuously monitoring or regularly checking that the equipment affected by energy efficiency measures continues to operate efficiently. M&V approaches based on ongoing measurements rather than one-time measurements are much more likely to ensure that energy savings persist. Technology is improving the cost-effectiveness of ongoing monitoring and M&V to support long-term achievement of savings.
- **Technology-enabled information support timely decision-making.** Technology significantly shortens the time frames around data throughput and the transformation of data to information and decisions. The days of waiting for a utility bill to monitor and manage energy usage and to perform M&V are disappearing. Building data, energy usage data, diagnostic results, and actionable information are readily available in real time or near real time (with short delays of one day or less). Decisions related to occupying, operating, maintaining, and upgrading buildings are prompt and data-driven.
- **Trust and transparency are enhanced.** Although the purpose of M&V is well understood, the design, calculations and results are sometimes confusing or misinterpreted, and that erodes trust between the parties involved. A well-designed and well-executed M&V plan greatly reduces the likelihood of dispute. Technology is helping to make M&V plans simple, consistent and transparent, in turn helping to build and maintain high levels of trust among all parties involved with energy efficiency.

GLOBAL PERSPECTIVES

While the building efficiency business is growing rapidly on a global basis, the maturity of the business and industry across regions varies dramatically. In general, North America and Europe have the most established industries, but countries such as Australia, Brazil, China and India are quickly establishing energy efficiency markets and replicating successful industry practices. These markets will continue to expand as governments look for strategies to balance rapid urbanization with sustainable development.

In these emerging markets, education is critical for establishing a robust and sustainable building energy efficiency business. Markets will develop best where governments, building owners, and product and service providers work together to build the required awareness and trust. While many countries are behind, they can catch up quickly by leveraging the knowledge and experience of more established countries. Technology enhancements in all aspects of the industry will help these countries quickly adopt proven practices. These emerging markets will further drive the sharing of industry practices and global standards, such as ISO 50001.

For M&V the IPMVP is used in more than 40 countries. However, in a recent survey of decision-makers responsible for managing commercial and public buildings and their energy use,⁹ certainty of savings was identified as one of the top five most significant barriers to growth of energy efficiency markets. In India and China, certainty of savings was ranked almost equally with the availability of capital as a key barrier. This is in stark contrast to the survey results from the U.S. and Europe, where availability of capital ranked two to three times higher than certainty of savings as barriers. This difference between emerging and mature markets is another indicator of the need for more education and awareness around M&V.

⁹ Johnson Controls (2011) "Global Energy Efficiency Indicator 2011." Available at: <http://www.institutebe.com/InstituteBE/media/Library/Resources/Energy%20Efficiency%20Indicator/EEI-2011-Global-Results.pdf>.

CONCLUSION

The application of information technologies to the M&V of savings from energy efficiency projects will dramatically change current industry practices and trends. Low-cost meters, advanced building sensors, and greater connectivity between building and business systems will create an explosion of data for use by building information systems. M&V applications using advanced statistical-based analytics will dramatically lower M&V costs, while increasing both accuracy and functionality. Integration of M&V with performance monitoring, fault detection and diagnostics, and energy information leverages the technology investments and increases the value derived from the data. The energy efficiency industry will need to review and update its governance to keep up. The automotive, financial and medical industries provide examples of how information technologies can rapidly change the building energy efficiency industry.

The Whole-Facility (Option C) Story

Thirty to 40 years ago, when a formal energy efficiency industry was just starting to emerge, there were no standard methods for M&V. The first attempts for verifying savings were simply to compare utility bills before and after an energy efficiency project. This quickly proved highly inaccurate due to the many variables, such as weather and occupancy patterns, that drive energy consumption in a building. However, the direction was set, and the industry focused on the use of utility bills to verify savings.

An approach using linear regression models on historical utility bill data for normalizing the bills quickly emerged. In the early days, this approach was referred to as the utility bill comparison approach. Later, it would be referred to as the whole-facility approach, and IPMVP option C.

Although eloquent, simple and consistent, the whole-facility approach proved challenging for many projects and expensive for some. The industry answered by developing retrofit isolation methods. These methods have become preferred as the industry pushed to reduce M&V costs.

However, there are some drawbacks to the direction the industry has taken:

- The interaction of measures is rarely accounted for properly, and in some cases they are totally ignored. With the current drive for greater energy reductions in buildings, larger projects with more measures are being developed. The interactions must be accounted for if savings are to be accurately calculated.
- Shorter-term M&V does not address a critical challenge for the persistence of energy savings. It is commonly understood that buildings quickly move away from good or optimal performance if not monitored closely and maintained. Long-term M&V with ongoing measurements includes the monitoring needed to ensure long-term energy efficiency.
- Recent trends for a more continuous approach to energy efficiency through management restructuring, behavioral modifications, and ongoing commissioning results in energy savings from many little actions and efficiency measures. Measuring the net effect of these actions and efficiency measures is not cost-effective using retrofit isolation approaches.

While technology can drive down the costs and improve the accuracy of all M&V, additional savings can be achieved by further standardization and consistency. With this in mind, it might be time to revisit the whole-facility regression model approach. Improved analytics allow this approach to be used on smaller projects with savings as little as 5 percent. More of the drivers that affect energy usage in a building can be incorporated into the model, improving its accuracy. In addition, unaccounted-for or non-recurring changes in a building can be quickly identified and the required adjustments determined. The whole-facility approach is independent of the measures being implemented and the type of building, systems and equipment to which they are applied. In other words, the same approach can be used every time, reducing costs and improving consistency across projects.

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