Integrated Framework toward a Closed Loop Measurement and Verification Approach

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ABSTRACT

This study reviews a sample set of measurement and verification (M&V) plans from federal ESPC projects to understand and assess the overall status of M&V practices. The review identifies some of the key issues that need to be addressed to improve the rigor and transparency of M&V practices. To mitigate some of the identified M&V issues, this work also reviews existing M&V protocols, guidelines and other pertinent literature to identify strategies that can augment traditional M&V approaches. The authors provide a framework to identify ways to integrate M&V and commissioning activities into the ESPC process, combining M&V activities and advanced meter data into a monitoring-based commissioning approach that reduces the uncertainty of savings while ensuring their persistence.

Introduction

Federal facility managers are challenged daily with maintaining aging buildings to achieve desired building occupant comfort needed to maintain worker productivity. Additionally, they are faced with congressional mandates to reduce energy use and operations and maintenance (O&M) expenses, albeit with little capital funding. One recent directive, the Energy Independence and Security Act of 2007 (EISA), requires federal agencies to reduce energy intensity by 3% annually beginning in FY 2006, up to a cumulative 30 percent reduction by the end of FY 2015 (compared to an FY 2003 baseline). Federal buildings are also required by the Energy Policy Act of 2005 (EPAct 2005) to be individually metered by October 1, 2012 in an effort to ensure efficient energy use with advanced meters.

Energy savings performance contracting (ESPC) provides a procurement mechanism to allow agencies to acquire performance-based services to implement energy-efficient equipment and systems that reduce energy use and O&M expenses through projects designed, installed, financed, and maintained by energy service companies (ESCOs). An ESPC project allows an agency to reallocate its utility and building O&M expenses to pay for energy system infrastructure improvements from the resulting cost savings. In ESPCs there are two principal goals: (1) to reduce building energy use (and related equipment O&M expenses), and (2) to meet or exceed facility performance requirements, such as lighting and temperature levels. Measurement and verification (M&V) primarily focuses on the former goal while commissioning (Cx) focuses primarily on the latter. M&V is the process of ensuring that the savings proposed by energy efficiency projects are generated with a certain degree of confidence. M&V in federal ESPCs is primarily conducted by the ESCO. The M&V plan constitutes part of the ESPC's terms and defines a strategy to ensure that the project is performing and demonstrating the proposed level of guaranteed savings. Since the savings cannot be measured directly, the M&V plan is essentially based on comparing the baseline energy consumption with its post-retrofit usage by gathering measurements on variables affected by the project or a measure. The M&V strategy can focus on a sub-system or entire building or facility impacted by the energy efficiency project. However the M&V strategy should aim to strike an optimal balance between the performance risks and the costs involved for these efforts.

Regarding the EPAct 2005 requirement that federal buildings install advanced electrical meters, these have been defined as meters that are capable of providing data at least daily and measuring the consumption of electricity at least hourly. These data, coupled with data from the energy management control systems, provide an opportunity to leverage and conduct more robust and cost-effective M&V. The output can not only be harnessed to measure, analyze and verify energy consumption of the buildings but also to rectify problems on a real-time basis so that performance problems do not persist and energy savings are not sacrificed.

Background

Measurement and Verification

There are currently three broadly used M&V documents in the U.S.: the International Performance Measurement and Verification Protocol (IPMVP 2007), the Federal Energy Management Program's (FEMP) M&V Guidelines (v. 3.0, 2008) and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers' (ASHRAE) Guideline 14 (2002). Each offers varying degrees of M&V guidance, from providing a general framework for measuring energy efficiency projects to offering specific M&V plan templates for particular energy conservation measures (ECMs). IPMVP, FEMP and ASHRAE provide an array of "options" to verify savings. IPMVP and FEMP categorize these options as either retrofit isolation (Options A and B) or whole-facility (Options C and D) techniques. Retrofit isolation options assess the affected equipment or system (such as a chiller or set of fixtures) independent from the rest of the facility. Whole-facility (or whole-building) methods consider the total energy use of the facility. The primary difference in these approaches is where the boundary of the ECM is drawn: in options A and B, that boundary is drawn around the retrofitted piece(s) of equipment, whereas with options C and D, the boundary includes the whole building or facility.

The IPMVP offers an overall framework of definitions and broad approaches for verifying the savings in commercial and industrial energy efficiency projects. It also presents procedures to design an M&V program with varying levels of accuracy in order to manage the associated M&V costs.

The FEMP M&V Guidelines is an application of the IPMVP specifically intended for use on federal projects, especially ESPCs. The "performance" aspect of these contracts is associated with a savings guarantee from the contractors and relies heavily on the way that the savings are determined. Since the M&V approach dictates the means for calculating and documenting energy savings, it is one of the most important aspects of performance contracts and is a crucial issue in contract negotiations. The FEMP guidelines offer more detailed guidance than the IPMVP on the application of different M&V options for specific energy conservation measures. In keeping with their applications emphasis, the guidelines provide procedural and content checklists for conducting proper M&V; standard M&V plan templates for two common ECMs (lighting retrofits and chiller replacements) are also provided.

ASHRAE Guideline 14 provides additional details on implementing M&V plans within the IPMVP framework. Where IPMVP and FEMP make a provision for limited M&V under Option A, ASHRAE requires comprehensive metering for all options and does not permit Option

A or any equivalent. IPMVP's discussions on balancing of uncertainty and cost are enhanced by ASHRAE's description of ways to quantify uncertainty so that project hosts and designers can consider costs in light of the best available methods for quantifying uncertainty.

Commissioning

Commissioning (Cx) is the systematic process of assuring through verification and documentation that all facility systems perform in accordance with the design documentation and intent. This should also be a reflection of the owner's operational needs and include preparation of operational personnel. Cx ensures that all of the equipment and systems within a facility are currently operating and functioning properly, and identifies items that need to be fixed or adjusted, typically in a low- or no-cost fashion. Retro-commissioning (RCx) involves commissioning of equipment or a system that was not commissioned at the time of installation or during the warranty phase. Re-commissioning is the process of commissioning a previously commissioned facility or system after expiration of the warranty phase. The primary goal of re- and retro-commissioning is to optimize facility performance in accordance with design or operating needs over the useful life of the facility.

Monitoring-based commissioning (MBCx) uses energy consumption and system-performance monitoring to guide the re- and retro-commissioning processes for existing buildings and to verify the energy savings achieved. Furthermore, monitoring is used to help ensure the persistence of savings by alerting building staff and management to degradation in performance and faults in operation. Monitoring can help identify improvement opportunities during re- and retro-commissioning continuously providing data during building operation; it can also support continous commissioning and renewal of building systems.

A large number of state university campuses within the University of California (UC) and California State University (CSU) systems recently employed MBCx across their existing buildings. This project involved the installation and upgrade of permanent energy meters and other instrumentation, augmentation of energy information systems (EIS), benchmarking of building energy performance, assistance with initial commissioning efforts, and training of in-house staff. The universities, in partnership with California's investor-owned utilities (IOUs), established a permanent framework for a long-term, comprehensive energy management program at the 33 UC and CSU campuses served by the IOUs. Based on the preliminary results, MBCx reduced total annual energy use by a median value of 10 percent in the portfolio of buildings, with a median payback period of 2.4 years.

A 2008 study by the California Commissioning Collaborative (CCC) reviewed existing methods and practices to verify savings in RCx projects and programs. Partly based on this work, CCC issued M&V guidance to help verify savings in existing building commissioning (EBCx) projects using interval data energy models, (IPMVP Options B and C). *Guidelines for verifying existing building commissioning project savings* is designed to help commissioning service providers, building owners and managers, and energy efficiency program managers to understand how to design and manage robust M&V procedures within individual EBCx projects. It provides guidance on designing M&V strategies, identifying and using data resources, selecting an energy modeling methodology, scheduling M&V activities within the process of an EBCx project, and leveraging the many synergies between the IPMVP and ASHRAE processes. This EBCx-M&V guideline describes two M&V approaches, system isolation (Option B) and whole-building (Option C). The latter utilizes short-term interval data, energy modeling based on statistical regressions, and change-point models (models of energy as a function of heating and cooling degree days).

Turner, et al. examined ten buildings that were retro-commissioned in order to investigate the persistence of RCx efforts. The team employed an IPMVP Option C approach, gathering buildings' energy meter data. Their analysis included nine months of baseline data and three years of post-commissioning data. They also measured hourly data for chilled water, hot water and electricity from an energy information system, as well as ambient temperature. Their research showed that three to four years after commissioning, about 80% of the energy savings persisted in most of the buildings studied. Based on the results of this study, it was concluded that- basic RCx measures are quite stable; savings should be monitored to determine the need for follow-up; steps should be taken to inform operators of the impact of planned/implemented control change.

Similarly, Bourassa, et. al. conducted a persistence study for buildings retro-commissioned in the Sacramento Municipal Utility District's program in 1999-2000. In place of hourly interval data, the team used an alternative Option C approach using monthly utility bill data. The energy analysis indicated that during the first two years after RCx the savings generally increased. This was expected because of the length of time needed for the RCx measures to be implemented. In the third year the savings began to level off, and energy savings started degrading during the fourth year after retro-commissioning.

Bou-Saada and Culp described the benefits of a long-term performance contract between the Texas Health and Human Services Commission, which included 23 campuses of mental health facilities throughout the state and delivered $4 million per year in savings. This project employed M&V based on IPMVP or ASHRAE Guideline 14. Utility bill analysis (Option C) and calibrated simulation (Option D) were used. Jump et. al. described an Option B (retrofit isolation, all parameters) approach integrated within an MBCx project at UC Berkeley. The energy use in the building's heating ventilation and air-conditioning (HVAC) systems was tracked and savings quantified for all measures that affected those systems. In order to track energy use in the individual systems, equipment was characterized as either having constant or variable loads so that appropriate proxy variables for energy use could be established. A regression model for energy use of the HVAC system was developed to calculate the baseline energy consumption. This baseline energy consumption, as predicted by the regression model, was compared with post-installation energy use to determine savings. This technique could be programmed into the energy management and control system (EMCS) and used by building operators to check daily performance and track savings.

Current M&V Practices in ESPC Projects

M&V plans and associated M&V activities for federal ESPC projects are developed in accordance with FEMP M&V Guidelines 3.0. These guidelines like IPMVP are not intended to be prescriptive regarding which M&V options should be used for which types of ECMs nor what parameters need to be measured and at what times. They define the various options and provide a general framework for the M&V for energy efficiency projects and measures. They are intended to help develop a project-specific M&V strategy to ensure that the project is performing and demonstrating the proposed level of guarantee. But since these guidelines do not provide any specific M&V strategy for given ECMs, they are interpreted and applied differently by different users (e.g., ESCOs).

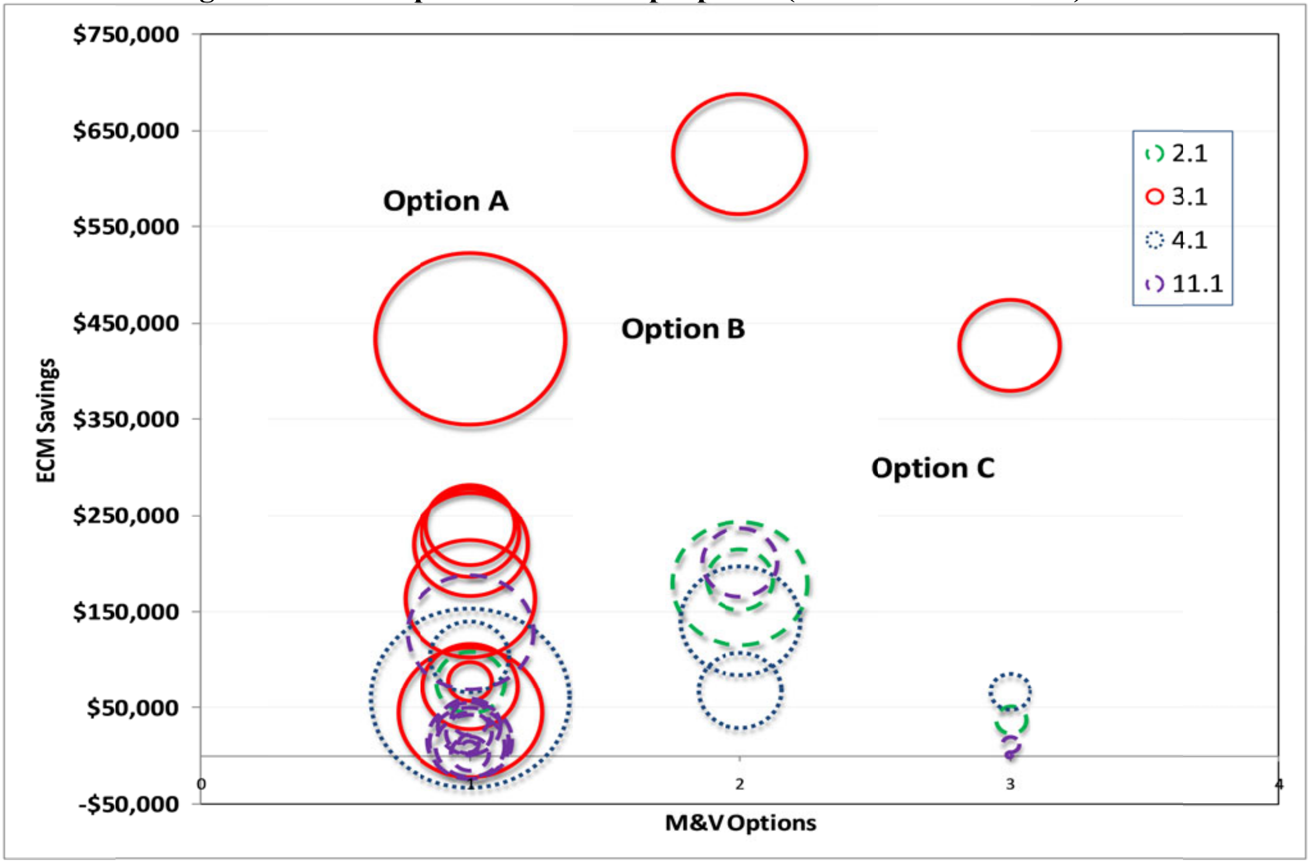
The purpose of M&V in ESPC is to reduce the total risk and to apportion the balance of the risk between the two parties. By verifying that savings are materializing as intended, the host site's risk of overpayment is reduced. Verification assigns the project risk to the ESCO, which is responsible for ensuring that installed measures are working properly and savings are being generated.

The different options described in the FEMP M&V Guidelines have different implementation costs and levels of rigor. Option A has the lowest M&V cost but generally provides the least certainty of claimed savings. Option B (retrofit isolation with all parameter measurement) is considerably more accurate but has higher M&V costs. Option C (whole building analysis) can be implemented with higher degrees of certainty and cost but performance of individual ECMs cannot be isolated. Computer simulation (Option D) is labor and cost-intensive but can be used for new construction or other projects where real baseline data do not exist.

Based on the M&V plans reviewed from recent federal ESPC projects, the authors feel that the overall state of M&V practices in these projects is weak and lacks the necessary rigor to ensure that the energy savings guaranteed by the ESCO are being realized with sufficient confidence. Frequently, the M&V option chosen is one that is inappropriate given the complexity of the ECM. As a specific example, there is a heavy reliance on M&V Option A (retrofit isolation with key parameter isolation) -- 80% of all savings from all ESPC projects (1998-2007) completed under the government's major umbrella contract is being verified using Option A. While Option A is appropriate for the simplest, least interactive ECMs, such as standard lighting and plumbing fixture replacements, much more complex ECMs like chiller replacements (2.1), EMCS upgrades (3.1), HVAC upgrades (4.1) and renewable energy measures (11.1) also frequently used Option A (Figure 1). Another common instance of poorly selected M&V is building simulations (often with inadequate calibration from metered data), which were frequently used for control system installations and modifications, even where metered data were available.

The authors found that some of the M&V plans neither outlined the energy savings calculation methodology nor specified underlying assumptions. Since most of the ECMs used M&V Option A, without such details it was very hard to know how the savings were calculated and even what the "key parameter" was. The absence of these details and the necessary transparency considerably increases the savings uncertainty for the federal government. In some of these cases, this lack of transparency resulted in out-of-proportion energy savings in relation to the baseline energy consumption. In order to combat some of these issues, FEMP has issued guidelines and documents to help conduct and support transparent M&V practices in federal ESPC projects. As an example, FEMP developed, through a working group authorized by the Federal ESPC Steering Committee, prescriptive M&V templates that standardize the M&V approaches used for two common ECMs in federal ESPCs, lighting retrofits and chiller replacements.

Figure 1. M&V Options for ECMs proposed (ESPC FY 2009 Data)



These standard M&V templates are unfortunately not being used frequently in federal ESPCs. Survey respondents, both ESCOs and agencies, cited lack of awareness and, in one case, perceived high cost of following the methodology outlined in these templates as reasons for their lack of use.

If the M&V in federal ESPC projects is not working, it is reasonable to then ask what kinds of alternatives would. To answer this, the purpose of M&V needs to be fully understood, and to some degree quantified. Project risk is related to both savings magnitude and uncertainty. Both components should be considered when determining project risk so that appropriate M&V efforts can be made. For example, a small lighting project with well-defined operating hours and a constant load will have a much smaller financial risk than a large, complex HVAC project.

To illustrate this concept, consider this project from the survey: a water conservation measure with guaranteed savings of $296,340 and a confidence interval of 20% and another EMCS upgrade ECM with guaranteed savings of $2,202,000 and confidence interval of 20% (both proposed to use M&V option A). In this project, an agency is at far greater financial risk from the HVAC project than the lighting project, both in absolute and relative terms. The HVAC project may save between $1,761,000 and $2,642,000, but if the savings are below the guaranteed amount and not identified in the M&V report, then the agency is at risk of potentially losing up to $440,320 in savings (more than the entire water measure's savings). The purpose of M&V is to reduce financial risk to acceptable levels by reducing uncertainty. In the above scenario, most of the M&V effort should be concentrated on the HVAC project to reduce the agency's total risk. Reducing uncertainty and risk with M&V activities, however, increases project cost. Good M&V activities reduce uncertainty without significantly increasing project costs. In the example above, reducing the HVAC confidence interval from 20% to 10% will reduce the project uncertainty by $220,200.

M&V cost depends on the final M&V option selected. Using information from the reviewed projects' final proposals, the average annual M&V costs as a percentage of estimated annual energy cost savings is found to range from 2%-19% (the O&M cost savings from some of these projects were not included while computing this ratio, as there were no specific M&V activities associated with these savings). Generally, project capital costs increased with the number of measures, however, total M&V costs did not scale with the project capital cost or annual savings. A metric often cited in training courses is that annual M&V costs, as a rule of thumb, should not exceed 10% of the annual energy cost savings. Most of the projects' ratios exceeded this value, and these costs seemed relatively high given the prominence of Option A methods. Projects with smaller annual savings had a larger fraction of the savings dedicated to M&V services, presumably because there are some fixed costs associated with M&V services.

Conceptual Model of Integrating Commissioning and M&V

MBCx uses energy consumption and system performance monitoring, through advanced metering and EMCS, to guide the re- and retro-commissioning processes. Furthermore, this monitoring can be used to ensure the persistence of savings by identifying anomalies that will lead to degradation in performance. MBCx is defined as the "adjustment, maintenance or repair of existing equipment as opposed to upgrade of equipment." In this model, we use a broader definition of MBCx, which includes re- and retro-commissioning projects in which retrofits might be included.

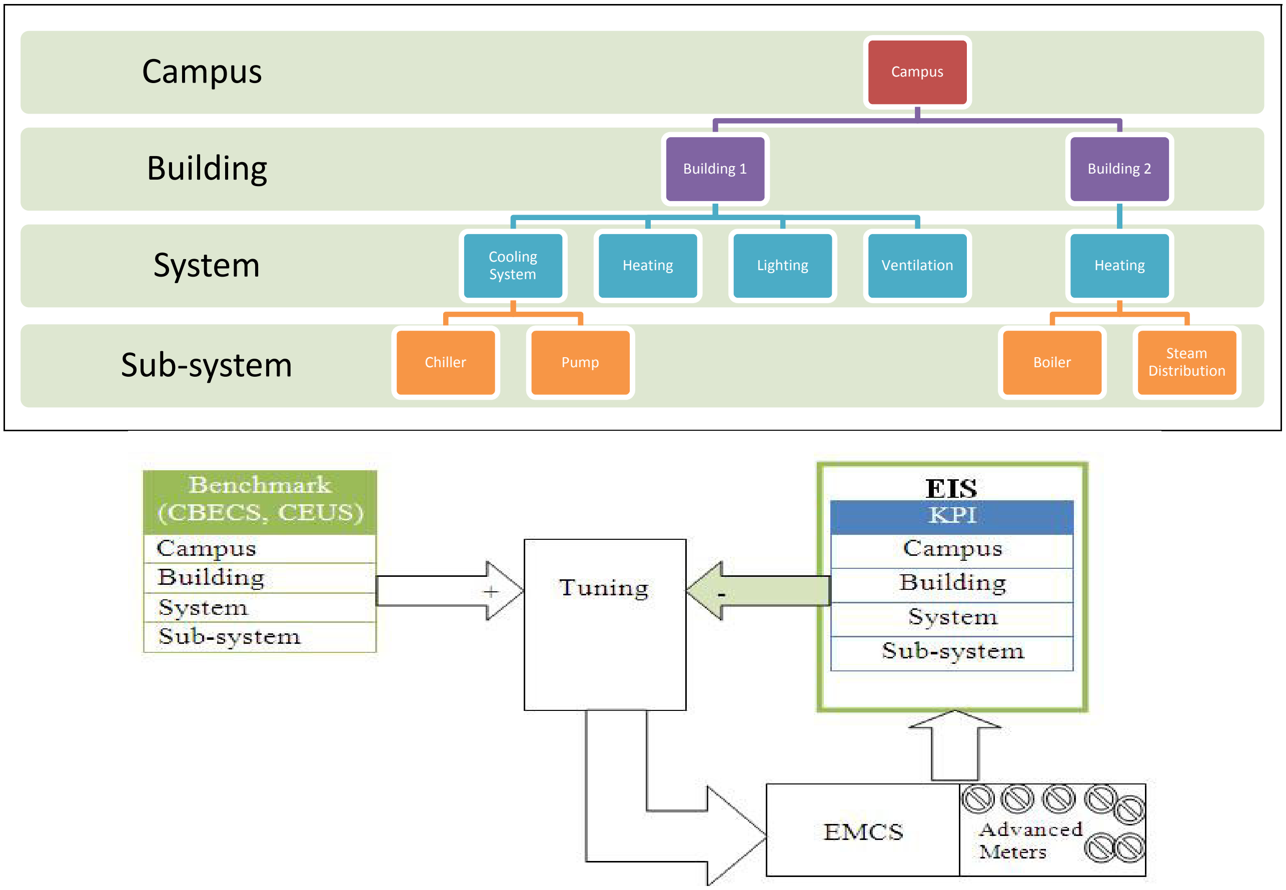
Traditionally, ESCO M&V personnel's involvement in ESPC project development is very minimal. Although in some instances ESCO project developers try to develop a clear idea of how the M&V should be conducted by involving the appropriate M&V personnel from the project's inception, it is more common for M&V to be appended to the project late in the development process without fully gauging the potential performance risks and associated costs.

The model proposed here tries to develop M&V strategy using the MBCx methodology and actively engaging ESCO M&V personnel with the rest of the project development team so that a better balanced M&V approach can be crafted. Table 1 provides a summary of the traditional federal ESPC phases along with associated M&V and commissioning activities, and then aligns this process with the MBCx process. The proposed integrated model (Figure 2) uses the data from advanced meters at federal buildings to conduct proactive M&V for ESPC projects by using the MBCx methodology and accordingly adjusting system parameters to ensure that the ECMs installed as part of ESPC projects are performing as intended.

Table 1. Comparison of M&V and Commissioning Activities in ESPC

Phase	ESPC Phase	M&V	Commissioning	EBCx/ MBCx
I	**Project Planning**	Define Objectives	Minimal Cx detail discussed	Identify purpose/goals of Cx activity, describe roles of involved parties, identify systems included in Cx process.
II	**Preliminary Assessment**	ESCO begins the development of M&V approach based on preliminary ECMs.	ESCO begins the development of project intent (PI) with input from agency that will be used to shape the Cx scope	Establish requirements, review available info, develop EBCx plan, interview operators, develop plan, document operating conditions
III	**Negotiate & Task Order Award**	Goals of the project defined and preliminary M&V approach identified along with M&V activities, risk and responsibilities	Goals of the project defined and draft PI issued, preliminary Cx approach identified, Cx activities, roles and responsibilities	Identify current building needs, facility performance analysis, diagnostic monitoring; list of ECMs/findings.
IV	**Design & Construction- Review of Design & Construction package**	Final M&V plan developed. Includes the list of M&V activities along with trends and other measurement variables for each ECM that will be collected	Final ECM Cx plan developed. Sequence of activities to commission equipment or systems will be written.	Prioritize recommendations, install/implement recommendations, functional test recommendations, document improved performance
IV	**Inspections, Cx & Acceptance**	ESCO submits interim post installation report, along with supporting documents. Conduct seasonal measurements as per M&V plan and final post installation report submitted.	ESCO submits interim Cx report, along with supporting documents. Conduct seasonal testing as per Cx plan and final Cx report submitted.	Update building documentation, develop final report, update systems manual, plan ongoing commissioning, provide training
V	**Performance Period**	Perform regular interval M&V activities		Monitor and track energy/non energy metrics, trend key system parameters, document changes, implement persistence strategies.

Figure 2: Integrated Framework for Pro-Active M&V



The proposed framework has the following components:

1. Data collection and processing (Granderson 2009): This function is mostly accomplished though an energy information system (EIS). EISs encompass software, data acquisition and storage hardware, and communication systems to store, analyze and display building energy information. An EIS retrieves whole building electric data, sub-metered data and other related parameters from subsystems, or components collected by an EMCS (Figure 3). These data are analyzed to calculate the key performance indicators (KPIs) at each level – building, system or sub-system of the hierarchy that specifies the energy performance. Some EMCSs can also double as EISs, by providing the capability to integrate whole-building utility meters and weather sensors, while still carrying out their traditional roles to monitor and control the building.
2. Benchmarking: There are several benchmarking tools in the market that can readily be used to compare the performance of the building with respect to other similar buildings. The most commonly used building energy benchmark is energy use intensity (EUI), usually measured in the U.S. in annual kBtu per square foot. “Distributional benchmarking” systems, such as Energy Star’s Portfolio Manager, compare a building's EUI to a population of similar buildings (Sharp, 1998). Percentile rankings are assigned based on the percentage of buildings that are worse performers (e.g., a score of 65 indicates that 65% of comparable buildings are more energy intensive), once adjusted for weather and operations. Benchmarking tools can also be categorized by the method in which benchmarking information is provided – statistical analysis, points-based rating

systems (such as the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED)), simulation model-based benchmarking, and “hierarchal and end-use” benchmarking (Sartor et al.). Hierarchical and end-use benchmarking is probably the most suitable and appropriate in the proposed framework. It shows the overall potential for reductions in energy intensity within each end use and its priority relative to other end uses. The Carbon Trust [Action Energy 2003] has demonstrated the application of end-use benchmarking to identify efficiency opportunities in office buildings in the United Kingdom. Another related technique, action-oriented benchmarking (Mathew & Mills 2008), extends generalized whole-building energy benchmarking to include analysis of system and component energy use metrics and features. This benchmarking coupled with the appropriate decision-tree logic, allows its users to identify, screen, and prioritize potential ECMs, and can in turn be used to inform and optimize a full-scale audit or commissioning process.

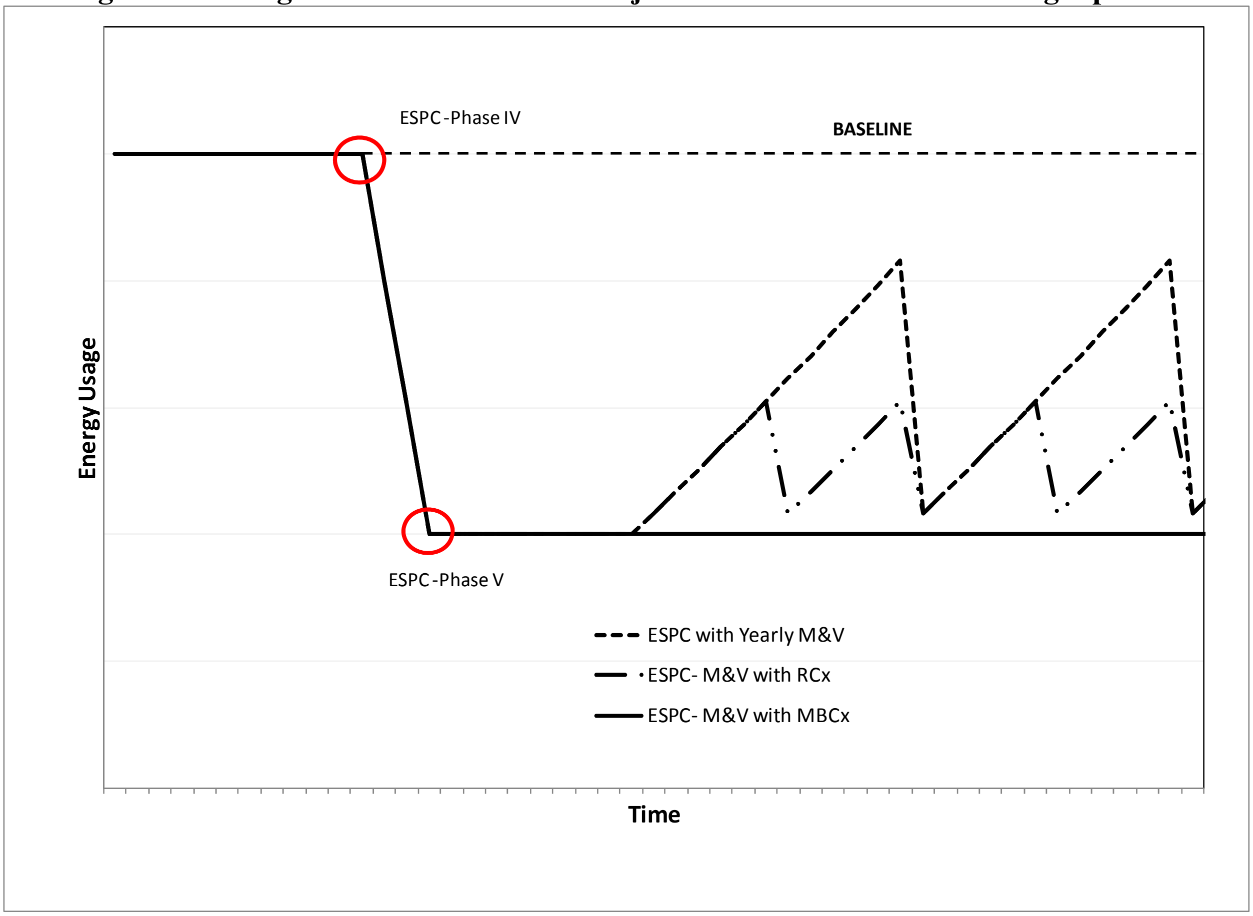
3. The process of “tuning” involves comparing the actual KPI information obtained from the EIS with the benchmarks (e.g., Commercial End-Use Survey CEUS) to generate corrective action based on the difference. The MBCx mechanism can be used to combine ongoing building energy system monitoring with standard re- or retro-commissioning (RCx) practices with the aim of providing substantial, persistent, energy savings [Brown and Anderson 2006]. Figure 3 shows three possible scenarios for energy savings in ESPC projects with retrofits – standard annual M&V, M&V with traditional RCx, and M&V with MBCx. By including the MBCx the savings generated from ESPC projects can be nearly assured to persist and can be optimized through proactive identification of deficiencies from metering and trending. Also, by adopting this mechanism of continuous monitoring, new energy conservation measures can be identified to further improve the energy efficiency of the building.

Conclusion

This paper reviews existing measurement and verification (M&V) protocols, guidelines and other pertinent literature that are currently being used to measure and evaluate the performance of energy efficiency improvement projects. It also highlights some of the M&V issues from federal ESPC projects based on a review of sample M&V plans from final proposals. The current M&V practices, based on the review, are considered weak and lack the necessary rigor to ensure that the savings from ESPC projects can be verified with an adequate degree of confidence. The existing M&V guidelines and protocols provide general guidance for M&V and do not provide direction for planning or conducting M&V given a project or ECM. Based on the review, the authors suggest that specific recommendations should be provided regarding what M&V options and strategies to use with different types of measures and projects based on technologies, risks, and costs.

This work also outlines the various M&V and commissioning activities typically undertaken during an ESPC project and identifies possible ways to align these to ensure that the M&V activities are more robust and transparent. Based on the literature survey, the authors propose an integrated M&V approach for combining the data from advanced utility meters to proactively monitor the performance of ESPC projects and drive commissioning activities as a way to ensure that the savings from these projects persist.

Figure 3. Savings Potential for ESPC Projects with Different Monitoring Options



Glossary of Abbreviations and Acronyms

M&V	Measurement and Verification
O&M	Operations and Maintenance
EISA	Energy Independence and Security Act
ESPC	Energy Savings Performance Contract
ESCO	Energy Services Company
EPAct 2005	Energy Policy Act of 2005
IPMVP	International Performance Measurement and Verification Protocol
ASHRAE	American Society of Heating, Refrigeration, and Air-conditioning Engineers
FEMP	Federal Energy Management Program
EMCS	Energy Monitoring and Controls System
EIS	Energy Information System
MBCx	Monitoring-based Commissioning
IOU	Investor-Owned Utility
HVAC	Heating Ventilation and Air-Conditioning
RCx	Retro- or Re-Commissioning
EBCx	Existing Building Commissioning

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