U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 4.0

Prepared for the U.S. Department of Energy
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FEMP
Federal Energy Management Program

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ABBREVIATIONS AND ACRONYMS

AHU	air handling unit
ASHRAE	American Society of Heating, Refrigerating, and Air Conditioning Engineers
C_v	coefficient of variation
DOE	US Department of Energy
ECM	energy conservation measure or water conservation measure
EMCS	energy management control system
ESCO	energy service company
ESPC	energy savings performance contract
FEMP	Federal Energy Management Program
HDD	heating degree day
HRU	heat recovery unit
HVAC	heating, ventilation, and air conditioning
IDIQ	indefinite delivery-indefinite quantity
IGA	investment grade audit (or feasibility study)
IPMVP	International Performance Measurement and Verification Protocol
M&V	measurement and verification
MATOC	multiple award task order contract (USACE)
MBE	mean bias error
NEMA	National Electrical Manufacturers Association
O&M	operations and maintenance
RMS	root mean square
RMSE	root mean square error
TES	thermal energy storage
TMY	typical meteorological year
USACE	US Army Corps of Engineers
VAV	variable air volume
VSD	variable speed drive

SECTION 1. INTRODUCTION

1.1 PURPOSE OF THE FEMP M&V GUIDE

This document contains procedures and guidelines for quantifying the savings resulting from energy efficiency equipment, water conservation, improved operation and maintenance, renewable energy, and cogeneration projects installed under performance-based contracts. For the purposes of this document, a performance-based contract means a contract in which a third party contractor (which may be an independent Energy Services Company [ESCO] or a utility provider) installs energy and water conservation equipment at a customer's facility and guarantees its level of performance and/or the resulting level of energy- and energy-related cost savings. Common terms for such contracts include Energy Savings Performance Contracts (ESPC), Energy Performance Contracts (EPC) and Utility Energy Service Contracts (UESC), which is a federal contracting vehicle in which energy services are provided through the serving utility. In this document, the terms ESPC and performance-based contract are used interchangeably, as are the terms ESCO and contractor.

This document is intended for energy managers, procurement officers, and contractors involved in implementing such measures. It has two primary purposes.

- It serves as a reference document for specifying M&V methods and procedures.
- It is a resource for those developing project-specific M&V plans.

The procedures defined in this document are impartial, reliable, and repeatable and can be applied with consistency to projects throughout all geographic regions. While the focus here is on performance-based contracts, the procedures can be adapted to determine savings from conservation measures installed in any project, regardless of funding source.

1.2 OTHER M&V GUIDELINES

Measuring and verifying savings from performance-based contracts requires special planning and engineering activities. Although M&V is an evolving science, industry best practices have been developed. These practices are documented in several guidelines, including the International Performance Measurement and Verification Protocol (IPMVP) and American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Guideline 14, *Measurement of Energy and Demand Savings*.[1, 2] These two guidelines are described below.

1.2.1 IPMVP

The IPMVP is a guidance document that provides a conceptual framework for measuring, computing, and reporting savings achieved by energy or water efficiency projects at facilities. It defines key terms and outlines issues that must be considered in developing an M&V plan.

1 *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings Volume I*, EVO-10000-1.2012, Efficiency Valuation Organization.

2 *ASHRAE Guideline 14-2015: Measurement of Energy, Demand and Water Savings*, American Society of Heating, Refrigerating, and Air Conditioning Engineers.

Developed through a collaborative effort involving industry, government, financial, and other organizations, the IPMVP serves as the framework for M&V procedures. It provides four M&V options and addresses issues related to the use of M&V in third-party-financed and utility projects.

The FEMP M&V Guideline contains specific procedures for applying concepts originating in the IPMVP. The Guideline represents a specific application of the IPMVP. It outlines procedures for determining M&V approaches, evaluating M&V plans and reports, and establishing the basis of payment for energy savings during the contract. These procedures are intended to be fully compatible and consistent with the IPMVP.

1.2.2 ASHRAE Guideline 14

ASHRAE Guideline 14, *Measurement of Energy, Demand and Water Savings,* is a reference for calculating energy and demand savings associated with performance contracts using measurements. In addition, it sets forth instrumentation and data management guidelines and describes methods for accounting for uncertainty associated with models and measurements. Guideline 14 does not discuss other issues related to performance contracting.

The ASHRAE guideline specifies three engineering approaches to M&V. Compliance with each approach requires that the overall uncertainty of the savings estimates be below prescribed thresholds. The three approaches presented are closely related to and support the options provided in IPMVP, except that Guideline 14 has no parallel approach to IPMVP/FEMP Option A.

1.2.3 DOE Uniform Methods Project

Under the Uniform Methods Project[3] (UMP), DOE is developing a set of protocols for determining savings from energy efficiency measures and programs. The protocols provide a straightforward method for evaluating gross energy savings for residential, commercial, and industrial measures commonly offered in ratepayer-funded programs in the United States. The measure protocols are based on a particular International Performance Verification and Measurement Protocol (IPMVP) option, but include additional procedures necessary to aggregate savings from individual projects in order to evaluate program-wide impacts.

For commercial measures, the FEMP guideline and the UMP are complementary. However, since one of the objectives of M&V in a performance-based project is to ensure long-term equipment performance, the FEMP guideline include additional recommendations for annual inspection and measurements, where appropriate.

[3] See http://energy.gov/eere/about-us/ump-home

The goal of measurement and verification (M&V) in a performance-based contract is to determine the energy, water, and cost savings that result from installation of efficiency measures. The challenge of M&V is to balance M&V costs with the value of increased certainty in the cost savings.

Properly applied, M&V can achieve the following.

- Allocate risks between the contractor and the customer
- Accurately assess energy savings and persistence of savings for a project
- Reduce uncertainties to reasonable levels
- Aid in monitoring equipment performance
- Identify additional savings
- Improve operations and maintenance (O&M)

2.1 GENERAL APPROACH TO M&V

M&V is the process of quantifying the energy and cost savings resulting from improvements in energy-consuming systems. The effort required and rigor achieved should be commensurate with the project capital investment and savings risk. Energy and cost reductions are compared to a historical baseline, which may be adjusted to reflect changing operating conditions or utility rates.

Facility energy (and water and O&M) savings cannot be measured because they represent the absence of energy/water use and expenditures. Instead, savings are determined by comparing resource use before and after the installation of energy conservation measures (ECMs), making appropriate adjustments for changes in conditions.

The "before" case is called the baseline. The "after" case is referred to as the post-installation or performance period. Proper determination of savings includes adjusting for changes that affect energy use but that are unrelated to equipment performance. Such adjustments may account for changes in weather, occupancy, or other factors between the baseline and performance periods. Equation 2-1 shows the general equation used to calculate savings.

Equation 2-1. General Equation Used to Calculate Savings

$$Savings = (Baseline\ Energy - Post\text{-}Installation\ Energy) \pm Adjustments$$

In the early days of the energy services industry, comparison of baseline and post-installation utility bills was the most common method of M&V.[4] While this method proved adequate in the

[4] Haberl, Jeff S., and Charles H. Culp. *Review of Methods for Measuring and Verifying Savings from Energy Conservation Retrofits to Existing Buildings*, ESL TR-03/09-01. Texas Engineering Experiment Station (Texas A&M University System) Energy Systems Laboratory, College Station, Texas, 2003 (revised April 2005); available online at http://repository.tamu.edu/bitstream/handle/1969.1/2049/ESL-TR-03-09-01.pdf?sequence=1&origin=publication_detail.

short term, it often led to difficulties in buildings and multibuilding facilities with varying patterns of energy use. Utility bills are affected by construction and demolition at the site, as well as by changes in occupancy and occupant behavior, mission, and plug loads. The need to track and account for such changes—i.e., the "Adjustments" in Equation 2.1—greatly increased informational requirements and ultimately the cost of performing M&V. This led to the development and use of M&V methods focused specifically on the installed conservation measures and the equipment they replaced.

Baseline and performance period energy use can be determined by using the methods associated with several different M&V approaches classified by the types of measurements performed. The four options, originating in the International Performance Measurement and Verification Protocol, are termed Options A (Retrofit Isolation with Key Parameter Measurement), B (Retrofit Isolation with All Parameter Measurement), C (Whole Facility Measurement), and D (Calibrated Simulation). (These options are discussed in Section 4 of this document.) The choice and use of a specific option are determined by the level of M&V rigor required to obtain the desired accuracy level in the savings determination and are dependent on the complexity of the project, the potential for changes in performance, each ECM's savings value, and the project's allocation of risk between the ESCO and the customer.

Two fundamental factors drive energy savings: performance and use. Performance describes how much energy is used to accomplish a specific task; use describes how much of the task is required, such as the number of operating hours during which a piece of equipment operates. For example, in the simple case of lighting, performance is the power required to provide a specific amount of light, and use is the operating hours per year. For a chiller (which is a more complex system), performance is defined as the energy required to provide a specific amount of cooling (which varies with load), whereas use is defined by the cooling load profile and the total amount of cooling required. Both performance and use factors need to be known to determine savings, as shown in Figure 2-1.

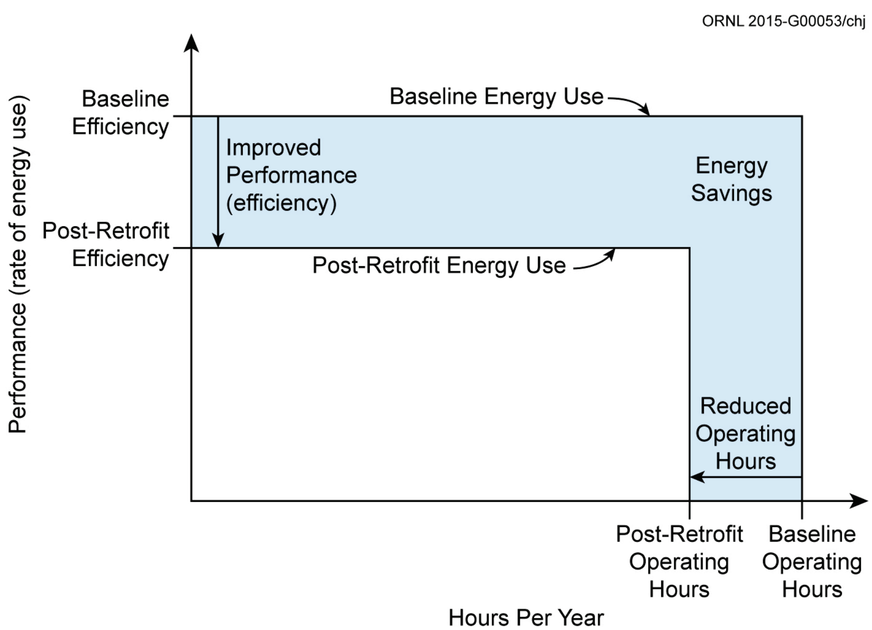

Figure 2-1. Energy Savings Depend on Performance and Use.

In Figure 2-1, the area of the large box represents the total energy used in the baseline case. Reduction in the rate of energy use (increase in performance) or reductions in use (decrease in operating hours) lead to reduced total energy use, which is represented by the smaller box. The difference between the two boxes—the shaded area—represents the energy savings.

M&V activities include site surveys, metering of energy and independent variables, engineering calculations, and reporting. How these activities are applied to determine energy savings depends on the characteristics of the ECMs being implemented and balancing accuracy in energy savings estimates with the cost of conducting M&V.

2.2 STEPS TO DETERMINE AND VERIFY SAVINGS

The sections below provide an overview of M&V activities in each phase of a project. Additional details on these topics are included in later sections.

2.2.1 Step 1: Allocate Project Risks and Responsibilities

The basis of any project-specific M&V plan is determined by the allocation of key project risks and responsibilities between the ESCO and the customer involved. A number of typical financial, operational, and performance issues must be considered when allocating risks and responsibilities. These issues are discussed in Section 3. The distribution of responsibilities will depend on the customer's resources and preferences, and the ESCO's ability to control certain factors.

2.2.2 Step 2: Develop a Project-Specific M&V Plan

The M&V plan defines how savings will be calculated and specifies any ongoing activities that will occur after equipment installation. The project-specific M&V plan includes project-wide items as well as details for each ECM. Project-wide items include the following.

- Overview of proposed energy and cost savings
- Schedule for all M&V activities
- Witnessing requirements
- Utility rates and the method used to calculate cost savings
- O&M reporting responsibilities

ECM-level items include the following.

- Details of baseline conditions and data collected
- Documentation of all assumptions and sources of data
- Details of engineering analysis performed
- The way energy savings will be calculated
- Details of any O&M or other cost savings claimed

- Details of proposed energy and cost savings
- Details of post-installation verification activities, including inspections, measurements, and analysis
- Details of any anticipated routine adjustments to baseline or reporting period energy
- Content and format of all required M&V reports (post-installation and periodic M&V)

A sample M&V plan outline is provided in Appendix C.

2.2.3 Step 3: Define the Baseline

Baseline physical conditions (such as equipment inventory and conditions, occupancy schedule, nameplate data, equipment operating schedules, key energy parameter measurements, current weather data, control strategies, etc.) are determined through surveys, inspections, spot measurements, and short-term metering activities. Utility bills may be used to verify that the baseline has been accurately defined depending on the M&V method selected. Baseline conditions are established for the purpose of estimating savings by comparing the baseline energy use with the post-installation energy use. Baseline information is also used to account for any changes that may occur during the performance period, which may require baseline energy use adjustments. It is important to ensure that the baseline has been properly defined.

Documentation of assumptions is also critical for baseline development. After the ECM has been implemented, it is impossible to go back and reevaluate the baseline because it no longer exists. Therefore, it is very important to properly define and document the baseline conditions. Deciding what needs to be monitored (and for how long) depends on such factors as the complexity of the measure and the stability of the baseline, including the variability of equipment loads and operating hours, and the other variables that affect the load.

2.2.4 Step 4: Install and Commission Equipment and Systems

Commissioning of installed equipment and systems is considered industry best practice. Commissioning ensures that systems are designed, installed, functionally tested in all modes of operation, and capable of being operated and maintained in conformity with the design intent (appropriate lighting levels, cooling capacity, comfortable temperatures, etc.).

Commissioning usually requires performance measurements to ensure that systems are working properly. Because of the overlap in commissioning and post-installation M&V activities, the two activities are sometimes confused. The difference is that commissioning ensures that systems are functioning properly, whereas post-installation M&V quantifies how well the systems are working from an energy standpoint.

2.2.5 Step 5: Conduct Post-Installation Verification Activities

Post-installation M&V activities are conducted to ensure that proper equipment/systems were installed, are operating correctly, and have the potential to generate the predicted savings. Verification methods include surveys, inspections, spot measurements, and short-term metering.

A post-installation M&V report is a key deliverable in an ESPC. The post-installation report includes the following.

- Project description
- Detailed list of installed equipment
- Details of any changes between the final proposal and as-built conditions, including any changes to the estimated energy savings
- Documentation of all post-installation verification activities and performance measurements conducted
- Performance verification—how performance criteria were met
- Documentation of construction-period savings (if any)
- Status of rebates or incentives (if any)
- Expected savings for the first year

An outline for the Post-Installation report is provided in Appendix D.

2.2.6 Step 6: Perform Regular-Interval M&V Activities

M&V must be performed at regular intervals to ensure that the installed equipment is operational and is delivering the savings that were proposed. In federal ESPC projects, M&V is performed on an annual basis. Other requirements for federal ESPCs are outlined in Appendix B.

Operational verification is an important part of the periodic M&V process. With proper coordination and planning, M&V activities that provide operational verification of an ECM (i.e., confirmation that the ECM is operating as intended) during the performance period can also support ongoing commissioning activities (e.g., recommissioning, retro-commissioning, or monitoring-based commissioning). ASHRAE Guideline 0, *The Commissioning Process*,[5] defines commissioning as "a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria." In the context of ESPC, where one of the objectives is to provide guaranteed cost savings, this definition aligns with the intent of M&V. Indeed, most forms of M&V require some periodic measurement of operational performance (or at a minimum, equipment inspection or trending of operational logs).

In federal ESPC projects, an annual report from the ESCO is required to document annual M&V activities and report verified and guaranteed savings for the year. In many cases, however, more frequent verification activities are appropriate. More frequent monitoring and/or inspection ensures that the M&V monitoring and reporting systems are working properly and installed equipment and systems are operating as intended throughout the year, allows fine-tuning of measures throughout the year based on operational feedback, and avoids surprises at the end of the year.

[5] ASHRAE, *The Commissioning Process*, ASHRAE Guideline 0-2013 (supersedes ASHRAE Guideline 0-2005), the American Society of Heating, Refrigerating, and Air Conditioning Engineers, 2013.

Annual reports in federal ESPC projects must include the following.

- Results/documentation of performance measurements and inspections
- Verified savings for the year (energy, energy costs, O&M costs, etc.)
- Comparison of verified savings with the guaranteed amounts
- Details of all analysis and savings calculations, including commodity rates used and any baseline adjustments performed
- Summary of operations and maintenance activities conducted
- Details of any performance or O&M issues that require attention

An outline for the Annual M&V Report is provided in Appendix E.

SECTION 3. RISK AND RESPONSIBILITY IN M&V

3.1 USING M&V TO MANAGE RISK

At the heart of an ESPC is a guarantee of a specified level of cost savings and performance. One of the primary purposes of M&V is to reduce the risk of nonperformance to an acceptable level, which is a subjective judgment based on the customer's priorities and preferences. In an ESPC, project risks and responsibilities are allocated between the ESCO and the customer. In the context of M&V, the word "risk" refers to the uncertainty that the expected savings will be realized, including the potential monetary consequences.

The allocation of responsibilities between the ESCO and the customer drives the M&V strategy, which actually defines the specifics of how fulfillment of the savings guarantee will be determined. Both the ESCO and the customer are reluctant to assume responsibility for factors they cannot control.

A few fundamental principles can be applied to the allocation of responsibilities in ESPC agreements.

- Logic and cost-effectiveness drive the allocation of responsibilities.
- The responsible party predicts its likely tasks and associated costs to fulfill its responsibilities and makes sure these are covered in the ESPC or the customer's budget.
- Any unforeseen costs are paid by the party that caused the costs or by the party responsible for that risk area.
- Stipulating certain parameters in the M&V plan can align responsibilities, especially for the items no one controls.

The risks in achieving energy savings can be allocated to use and performance factors. Risk related to use stems from uncertainty in operational factors. For example, savings fluctuate depending on weather, the number of hours in which equipment is used, user intervention, and equipment loads. Because ESCOs often have no control over such factors, they are usually reluctant to assume usage risk. The customer generally assumes responsibility for usage risk by either allowing baseline adjustments based on measurements or by agreeing to stipulated equipment operating hours, cooling load profiles, or other usage-related factors. Using stipulations means that the ESCO and customer agree to employ a set value for a parameter throughout the term of the contract, regardless of the actual behavior of that parameter.

The use of stipulations is a practical, cost-effective way to reduce M&V costs and allocate risks. Stipulations used appropriately do not jeopardize the savings guarantee, the customer's ability to pay for the project, or the overall value of the project to the customer. However, stipulations have the potential to shift risk to the customer, and the customer should understand the potential consequences before accepting them. Risk is minimized and optimally allocated through carefully crafted M&V requirements, including diligent estimation of any stipulated values.

3.2 RISK, RESPONSIBILITY, AND PERFORMANCE MATRIX

A project-specific risk, responsibility, and performance matrix (referred to below simply as the "responsibility matrix") is required for ESPC projects awarded under the DOE IDIQ ESPC and USACE MATOC, and is a useful tool for considering the risks in any ESPC project. This matrix details risks, responsibilities, and verification requirements that should be considered when developing performance contracts. The matrix is developed to help identify the important project risks, assess their potential implications, and clarify the party responsible for managing the risk.

The first step in developing an M&V plan for an ESPC project is the completion of a project-specific responsibility matrix. Early in the project development process, the ESCO and the customer review the responsibility matrix and evaluate how to allocate the key responsibilities.

The responsibility matrix, shown in Table 3-1, describes typical financial and operational issues and their influence on ESPC contracts. The table lists the primary factors that affect the determination of savings and illustrates how their definition indicates which party—the ESCO or the customer, or perhaps neither—will oversee the performance for each factor. These risks fall into three primary categories: financial, operational, and performance. Each category has several subcategories.

For federal ESPC projects, the responsibility matrix is first included in the preliminary assessment and finalized in the final proposal. A blank column in the responsibility matrix is completed by the ESCO to describe the proposed allocation of responsibilities in the project, and an additional column can be added for the agency's assessment. The final version will only contain allocations agreed upon by both the ESCO and agency.

Completing the responsibility matrix serves as a useful exercise in understanding the approaches required in the M&V plan because the matrix indicates what activities the ESCO will oversee and thus need to be documented during the life of the contract. The allocation of performance must take into account the customer's resources and preferences and the ESCO's ability to control certain factors. In general, a contract objective may be to release the ESCO from responsibility for factors beyond its control, such as building occupancy and weather, yet hold the ESCO responsible for controllable factors (risks) such as maintenance of equipment efficiency.

Performance risk is the uncertainty associated with characterizing a specified level of equipment performance. The ESCO is ultimately responsible for selection, application, design, installation, and performance of the equipment and typically assumes responsibility for achieving savings related to equipment performance. Operations, preventive maintenance, and repair and replacement practices can have a dramatic effect on equipment performance.

Table 3-1. Energy Savings Performance Contract Risk, Responsibility, and Performance Matrix[a]

Responsibility/Description	Contractor-Proposed Approach
1. Financial	
a. Interest rates: Neither the contractor nor the customer has significant control over prevailing interest rates. Higher interest rates will increase project cost, financing/project term, or both. The timing of the task order (TO) signing may impact the available interest rate and project cost.	
b. Construction costs: The contractor is responsible for determining construction costs and defining a budget. In a fixed-price design/build contract, the customer assumes little responsibility for cost overruns. However, if construction estimates are significantly greater than originally assumed, the contractor may find that the project or measure is no longer viable and drop it before TO award. In any design/build contract, the customer loses some design control. **Clarify design standards and the design approval process (including changes) and how costs will be reviewed.**	
c. Measurement and verification (M&V) confidence: The customer assumes the responsibility of determining the level confidence that it desires to have in the M&V program and energy savings determinations. The desired confidence will be reflected in the resources required for the M&V program, and the ESCO must consider the requirement before submitting the final proposal. **Clarify how project savings are being verified (e.g., equipment performance, operational factors, energy use) and the impact on M&V costs.**	
d. Energy-Related Cost Savings: The customer and the contractor may agree that the project will include savings from recurring and/or one-time costs. This may include one-time savings from avoided expenditures for projects that were appropriated but will no longer be necessary. Including one-time cost savings before the money has been appropriated may involve some risk to the customer. Recurring savings generally result from reduced operations and maintenance (O&M) expenses or reduced water consumption. These O&M and water savings must be based on actual spending reductions. **Clarify sources of nonenergy cost savings and how they will be verified.**	
e. Delays: Both the contractor and the customer can cause delays. Failure to implement a viable project in a timely manner costs the customer in the form of lost savings and can add cost to the project (e.g., construction interest, remobilization). **Clarify schedule and how delays will be handled.**	
f. Major changes in facility: customer controls major changes in facility use, including closure. **Clarify responsibilities in the event of a premature facility closure, loss of funding, or other major change.**	
2. Operational	
a. Operating hours: The customer generally has control over operating hours. Increases and decreases in operating hours can show up as increases or decreases in savings depending on the M&V method (e.g., operating hours multiplied by improved efficiency of equipment vs. whole facility/utility bill analysis). **Clarify whether operating hours are to be measured or stipulated and what the impact will be if they change.** If the operating hours are stipulated, the baseline should be carefully documented and agreed to by both parties.	
b. Load: Equipment loads can change over time. The customer generally has control over hours of operation, conditioned floor area, intensity of use (e.g., changes in occupancy or level of automation). Changes in load can show up as increases or decreases in "savings" depending on the M&V method. **Clarify whether equipment loads are to be measured or stipulated and what the impact will be if they change**. If the equipment loads are stipulated, the baseline should be carefully documented and agreed to by both parties.	
c. Weather: A number of energy and water conservation measures are affected by weather, which neither the contractor nor the customer has control over. Should the customer agree to accept risk for weather fluctuations, it will be contingent upon aggregate payments not exceeding aggregate savings. **Clearly specify how weather corrections will be performed.**	

Table 3-1. Energy Savings Performance Contract Risk, Responsibility, and Performance Matrix[a] (continued)

Responsibility/Description	Contractor-Proposed Approach
d. User participation: Many energy conservation measures require user participation to generate savings (e.g., control settings). The savings can be variable, and the contractor may be unwilling to invest in these measures. **Clarify what degree of user participation is needed and use monitoring and training to mitigate risk.** If performance is stipulated, document and review assumptions carefully and consider M&V to confirm the capacity to save (e.g., confirm that the controls are functioning properly).	
3. Performance	
a. Equipment performance: The contractor has control over the selection of equipment and is responsible for its proper installation, commissioning, and performance. The contractor has the responsibility to demonstrate that the new improvements meet expected performance levels, including specified equipment capacity, standards of service, and efficiency. **Clarify who is responsible for initial and long-term performance, how it will be verified, and what will be done if performance does not meet expectations.**	
b. Operations: Performance of the day-to-day operations activities is negotiable and can impact performance. However, the contractor bears the ultimate risk regardless of which party performs the activity. **Clarify which party will perform equipment operations, the implications of equipment control, how changes in operating procedures will be handled, and how proper operations will be assured.**	
c. Preventive Maintenance: Performance of day-to-day maintenance activities is negotiable and can impact performance. However, the contractor bears the ultimate risk regardless of which party performs the activity. **Clarify how long-term preventive maintenance will be ensured, especially if the party responsible for long-term performance is not responsible for maintenance (e.g., contractor provides maintenance checklist and reporting frequency). Clarify who is responsible for performing long-term preventive maintenance to maintain operational performance throughout the contract term. Clarify what will be done if inadequate preventive maintenance impacts performance.**	
d. Equipment Repair and Replacement: Performance of day-to-day repair and replacement of contractor-installed equipment is negotiable; however it is often tied to project performance. The contractor bears the ultimate risk regardless of which party performs the activity. **Clarify who is responsible for performing replacement of failed components or equipment replacement throughout the term of the contract. Specifically address potential impacts on performance due to equipment failure. Specify expected equipment life and warranties for all installed equipment. Discuss replacement responsibility when equipment life is shorter than the term of the contract.**	

[a]A similar Energy Savings Performance Contract (ESPC) risk, responsibility, and performance matrix is included in the US Department of Energy master ESPC indefinite delivery–indefinite quantity contracts. The US Army Corps of Engineers multiple award task order contracts include a similar matrix as well.

4.1 OVERVIEW OF M&V OPTIONS A, B, C, AND D

The International Performance Measurement and Verification Protocol (IPMVP) defines four broad categories of measurement and verification (M&V) techniques: Options A, B, C, and D. These categories are divided into two general types: retrofit isolation and whole facility. Retrofit isolation methods consider only the affected equipment or system independent of the rest of the facility. Whole facility methods consider the total energy use and de-emphasize specific equipment performance. The primary difference in these approaches is where the boundary of the energy conservation measure or water conservation measure (ECM) is drawn, as shown in Figure 4-1. To determine savings, all energy used within the boundary must be considered. Options A and B are retrofit isolation methods, Option C is a whole facility method, and Option D can be used as either but is usually applied as a whole facility method.

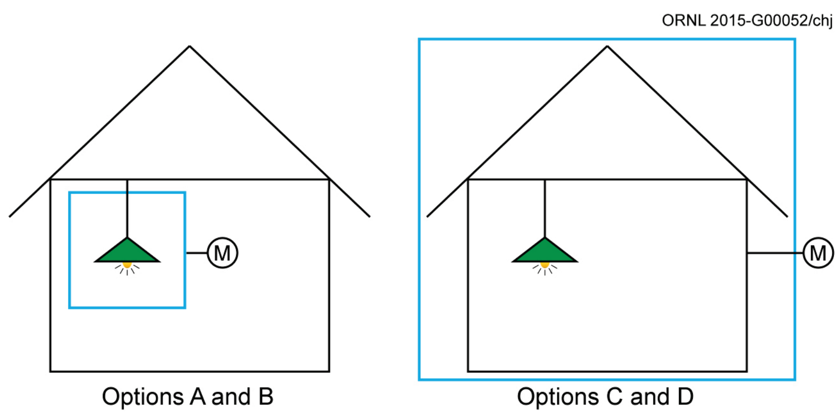

Figure 4-1. Retrofit Isolation (Options A and B) vs. Whole Facility Measurement and Verification Methods (Options C and D).

The four generic M&V options are summarized in Table 4-1 and described in more detail below. Each option has advantages and disadvantages based on site-specific factors and the needs and expectations of the customer. While each option defines an approach to determining savings, it is important to realize that savings are not directly measured, and all savings are estimated values. The accuracy of these estimates, however, will improve with the number and quality of the measurements made. The accuracy of savings estimates can be quantified, as discussed in the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Guideline 14, Appendix B.[2]

Table 4-1. Overview of Measurement and Verification Options A, B, C, and D

Measurement and Verification Options	Description	Examples
Option A—Retrofit Isolation with Key Parameter Measurement	This option is based on a combination of measured and estimated factors. Measurements are short-term, periodic, or continuous and are taken at the component or system level, for both the baseline and the retrofit equipment. Measurements should include the key performance parameters that define the energy use of the energy conservation measure. Estimated factors are supported by historical or manufacturers' data. Savings are determined by means of engineering calculations of baseline and reporting period energy use based on measured and estimated values.	Lighting retrofit projects. The key parameters are the power draws of the baseline and retrofit light fixtures. The operating hours are estimated based on facility use and occupant behavior. Energy savings are calculated as the difference in power draw multiplied by the operating hours.
Option B—Retrofit Isolation with All Parameter Measurement	This option is based on short-term, periodic, or continuous measurements of baseline and post-retrofit energy use (or proxies of energy use) taken at the component or system level. Savings are determined from analysis of baseline and reporting period energy use or proxies of energy use.	Installation of a variable speed drive and associated controls on an electric motor. Electric power is measured with a meter installed on the electrical supply to the motor. Power is measured during the baseline period to verify constant loading. The meter remains in place throughout the post-retrofit period to measure energy use. Energy savings are calculated as the pre-retrofit energy use (adjusted to correspond to the length of the reporting period) minus the measured energy use during the reporting period.
Option C—Whole Facility Measurement	This option is based on continuous measurement of energy use (such as utility billing data) at the whole facility or subfacility level during the baseline and post-retrofit periods. Savings are determined from analysis of baseline and reporting period energy data. Regression analysis is conducted to correlate energy use with independent variables such as weather and occupancy. Because this option requires a detailed inventory of all equipment included in the meter reading (as well as knowledge of equipment use patterns, building occupancy, and other factors affecting energy use), it is rarely used in federal projects. It can be appropriate for short periods or where equipment included in the meter reading is limited or can be controlled.	Replacement of a gas boiler. Using billed natural gas use data for 12 months during the baseline period, a baseline regression model is developed of monthly natural gas use with monthly heating degree days. Given the monthly heating degree days in a typical year at the site, the baseline model is used to determine baseline gas use in a typical year. Annually during the post-retrofit period a similar regression model is developed using billed natural gas and heating degree day data from the previous 12-month period. The reporting period model is normalized to determine natural gas use in a typical year. Savings are defined as the normalized baseline gas use minus the normalized reporting period gas use.

Table 4-1. Overview of Measurement and Verification Options A, B, C, and D (continued)

Measurement and Verification Options	Description	Examples
Option D—Calibrated Computer Simulation	Computer simulation software is used to model energy performance of a whole facility (or subfacility). Models must be calibrated with actual hourly or monthly billing data from the facility. Implementation of simulation modeling requires engineering expertise. Inputs to the model may include facility characteristics; performance specifications of new and existing equipment or systems; engineering estimates; spot, short-term, or long-term measurements of energy use of system components; and long-term whole building utility meter data. After the model has been calibrated, savings are determined by comparing a simulation of the baseline with either a simulation of the performance period or actual utility data.	Comprehensive retrofit involving multiple interactive conservation measures in a large building. A simulation model of the building with baseline equipment is developed and calibrated to a minimum of 12 months of utility billing data. The baseline model is used to determine baseline energy use in a typical year at the site. Retrofit measures are implemented in the simulation model, and the model is run to estimate the post-retrofit energy use in a typical year. Energy use is determined as baseline energy use minus reporting period energy use. Spot measurements of equipment are made during the performance period to ensure that equipment performance conforms to the parameters used in the model.

4.2 OPTION A—RETROFIT ISOLATION WITH KEY PARAMETER MEASUREMENT

M&V Option A involves a retrofit or system level M&V assessment. The approach is intended for retrofits where key performance factors (e.g., end-use capacity, demand, power) or operational factors (e.g., lighting operational hours, cooling ton-hours) can be spot- or short-term-measured during the baseline period and periodically during the post-installation period. Any factor not measured is estimated based on assumptions or analysis of historical or manufacturers' data and considered a stipulated value.

All end-use technologies can be verified using Option A. However, the accuracy of this option is generally inversely proportional to the complexity of the measure. Thus, the savings from a simple lighting retrofit will typically be more accurately estimated with Option A than the savings from a more complicated chiller retrofit. If greater accuracy is required, Options B, C, or D may be more appropriate. Properly applied, an Option A approach

- ensures that baseline conditions have been properly defined,
- confirms that the proper equipment/systems were installed and that they have the potential to generate predicted savings, and
- verifies that the installed equipment/systems continues to yield the predicted savings during the term of the contract

Option A can be applied when identifying that the potential to generate savings is the most critical M&V issue, including situations where

- the magnitude of savings is low for the entire project or a portion of the project to which Option A is applied,
- the risk of not achieving savings is low,
- the independent variables that drive energy use are not difficult or expensive to measure,
- interactive effects can be reasonably estimated or ignored, and
- the customer is willing to accept some uncertainty.

4.2.1 Approach to Option A

Option A is an approach designed for measures in which the potential to generate savings must be verified, but the actual savings can be determined from short-term measurements, estimates, and engineering calculations. Ideally these short-term measurements should be repeated at least annually during the M&V process. Measurements of key parameters can be an important part of the annual operational verification process. In some cases, however, where the key parameter is not expected to change significantly over time, a single measurement during the post-installation period may be sufficient. Inspections and other operational verification activities are then performed at regular intervals during the post-installation period.

With Option A, savings are determined by measuring key parameters, such as capacity, efficiency, or operation of a system, before the retrofit and periodically during the performance period and multiplying the difference by an estimated factor. Using estimates is the easiest and least expensive method of determining savings. It can also be the least accurate and is typically the method with the greatest uncertainty in savings. This level of savings determination may suffice for certain types of projects where a single factor represents a significant portion of the savings uncertainty.

Where multiple pieces of identical equipment are to be installed, it is often more cost effective to perform the key parameter measurements on a random sample of the installed equipment. The size of the sample is defined by the desired precision and confidence level of the savings estimate (see IPMVP volume on Statistics and Uncertainty, EVO 10100-1:2014).

4.2.1.1 Measurements

Within Option A, various methods and levels of accuracy determining savings are available. The level of accuracy depends on what measurements are made to verify equipment ratings, capacity, operating hours, and/or efficiencies; the quality of assumptions made; and the accuracy of the equipment inventory including nameplate data and quantity of installed equipment. There may be sizable differences between published information and actual operating data. Where discrepancies exist or are believed to exist, field-operating data should be obtained.

A key consideration in implementing Option A is identifying the parameters that will be measured and those that will be estimated. For example, watts per fixture is the key performance parameter for a lighting retrofit.

Other parameters that affect energy use (e.g., operating hours) can be estimated and then stipulated during the post-installation period. Where these other parameters are not known with sufficient certainty, they should be measured in the baseline case and then stipulated. Appropriate sources of estimated values are discussed below.

4.2.1.2 Estimates

The estimated parameters will affect the reported savings over the entire post-installation period. All estimates should be based on reliable, documentable sources and should be known with a high degree of confidence. While direct measurements from short-term logging or existing EMCS records are the preferred information source, such information may not be available or may be costly to obtain. Sources of information on which estimations should be based include the following (in decreasing order of preference).

- Models derived from measurements and monitoring
- Manufacturers' data or standard tables (such as lighting tables used in utility demand-side management programs)
- Manufacturers' curves, such as pump, fan, and chiller performance curves
- Industry-accepted performance curves, such as standards published by the American National Standards Institute; the Air Conditioning, Heating, and Refrigeration Institute; and ASHRAE
- Typical meteorological year (TMY) weather data
- Observations of building and occupant behavior
- Facility operations and maintenance logs

Estimated parameters should *not* come from the following.

- Undocumented assumptions or rules of thumb
- Proprietary black box algorithms or other undocumented software
- Handshake agreements with no supporting documentation
- Guesses at operating parameters
- Equations that do not make mathematical sense or are derived from questionable data

4.2.2 M&V Considerations

Some considerations when using Option A approaches include the following.

- Option A methods can vary in the level of accuracy in determining savings and verifying performance. The level of accuracy depends on the validity of estimates, the quality of the equipment inventory, the measurements that are made, the frequency of the measurements, and the size of the sample (if a sampled approach is taken).
- Verifying proper ongoing operation and potential to perform is an important aspect of Option A.
- Option A is appropriate for relatively simple ECMs whose baseline and post-installation conditions (e.g., equipment quantities and ratings such as lamp wattages or motor kilowatts) represent a significant portion of the uncertainty associated with the project.

4.3 OPTION B—RETROFIT ISOLATION WITH ALL PARAMETER MEASUREMENT

M&V Option B is a retrofit isolation or system level approach. The approach is intended for ECMs with performance factors (e.g., end-use capacity, demand, power) and operational factors (lighting operational hours, cooling ton-hours) that can be measured at the component or system level. It is similar to Option A but uses periodic or continuous metering of all energy quantities, or all parameters needed to calculate energy, during the performance period. This approach provides higher accuracy in the calculation of savings but increases the M&V cost.

The objective of Option B is to calculate the same things as Option A, but Option B uses periodic or continuous measurement of all parameters needed to calculate energy use.

Option B is typically used when any or all of the following conditions apply.

- Energy savings values per individual measure are desired.
- Interactive effects can be estimated using methods that do not involve long-term measurements.
- Independent variables that affect energy use are not complex and excessively difficult or expensive to monitor.
- Operational data on the equipment are available through control systems.
- Submeters already exist that record the energy use of subsystems under consideration [e.g., a separate submeter for heating, ventilation, and air conditioning (HVAC) systems].

4.3.1 Approach to Option B

In Option B the potential to generate savings is verified through observations; inspections; and spot, short-term, or continuous metering of energy or proven proxies of energy use. Baseline models are typically developed by correlating metered energy use with key independent variables. Depending on the ECM, spot or short-term metering may be sufficient to characterize the baseline condition, with metering of one or more variables after retrofit installation. It is appropriate to use spot or short-term measurements in the post-installation period to determine energy savings when variations in performance are not expected. When variations are expected, it is appropriate to measure factors continuously during the post-installation period. Continuous monitoring of information can be used to improve or optimize the operation of the equipment over time, thereby improving the performance of the retrofit.

4.3.2 M&V Considerations

Option B is appropriate for measures in which the actual energy use needs to be measured for comparison with the baseline model for calculating savings. Considerations when using Option B approaches include the following.

- All end-use technologies can be verified with Option B; however, the degree of difficulty and costs associated with verification increase as metering complexity increases.

- Measuring or determining energy savings using Option B can be more difficult and costly than with Option A. However, results are typically more precise using Option B than the estimations defined for Option A.
- Periodic spot or short-term measurements of factors are appropriate when variations in loads and operation are not expected. When variations are expected, it is appropriate to measure factors continuously.
- Performing continuous measurements or periodic measurements at regular intervals will account for operating variations and will result in reduced uncertainty in the savings delivered. Continuous measurements provide long-term persistence data on the energy use of the equipment or system.
- Data collected for energy savings calculations can be used to improve or optimize the operation of the equipment on a real-time basis, thereby improving the benefit of the retrofit. For constant-load retrofits, however, there may be no inherent benefit to continuous over short-term measurements.

4.4 OPTION C—WHOLE FACILITY MEASUREMENT

M&V Option C involves whole facility, utility, or submeter data analysis procedures to verify the performance of retrofit projects in which whole facility baseline and performance period data are available. Because utility meters are the basis for utility costs, analysis of baseline and post-retrofit utility bills (or other whole facility meter data) is sometimes believed to be the most appropriate way to determine savings. In practice, however, Option C techniques are rarely used in ESPC projects. The following are among the reasons for this.

- A project in a multibuilding facility often involves only a small subset of the buildings, while the utility meter measures energy use across the entire facility. In these situations, changes in metered energy use due to energy savings in the treated buildings may be obscured by changes in the wider facility, including new construction, demolition, and mission changes.
- Where building meters have been installed by a party other than the utility, the meters must be maintained and calibrated and their data collected and stored. Data from these meters are often difficult to obtain and may be incomplete and/or of questionable accuracy.
- Even when accurate metered data are available for the treated buildings, over time, changes in occupancy, mission, and connected plug loads require additional—and potentially more complicated—adjustments to the baseline. Accounting for these changes increases informational requirements and the cost of performing M&V. Savings become more and more dependent on the adjustments and less dependent on the utility bills themselves.
- Analysis of whole facility energy use is not always a very accurate method of estimating savings. The standard error of the savings estimate depends on the variability of energy use in the building (due to occupant behavior, patterns of equipment use, etc.) and on weather conditions in the baseline and post-retrofit periods.
- On its own, whole facility measurement does not provide the system level data needed to ensure optimal performance of specific ECMs.

Option C regression methods can be useful for determining savings from multiple interactive ECMs and for determining the benefit of projects that cannot be measured directly such as those involving insulation or other building envelope measures. Regression analysis requires experienced, qualified analysts; therefore, Option C methods should be used only for projects that meet the following requirements.

- Savings are predicted to be greater than about 10% to 20% of the overall consumption measured by the utility or submeter on a monthly basis.
- At least 12 (preferably 24) months or more of pre-installation data are available to calculate a baseline model.
- At least 9 (preferably 12) months of performance period data are used to calculate annual savings.
- Adequate data on independent variables are available to generate an accurate baseline model, and procedures are in place to track the variables required for performance period models.
- Loads on the meter aside from those involved in the retrofit are small and expected to remain constant over time or are inventoried during the baseline and performance periods along with other information affecting their energy use such as building occupancy, occupant behavior, and patterns of use.

Furthermore, given the changes in energy use that occur in most buildings with changes in mission, occupancy, and equipment loads, Option C is often more appropriate for use on a short-term basis (i.e., 2–3 years). Once savings are established, the M&V process can be switched to a retrofit isolation technique such as Option A or B.

4.4.1 Approach to Option C

With Option C, energy savings are determined using whole facility utility meter or facility-level metered data. Savings are determined through analysis of utility or metered data (therms, fuel oil, kilowatts, kilowatt-hours, etc.) and the independent variables that affect energy consumption. Regression models are developed to predict energy use based on the appropriate independent variables for the project. Regression models can take into account the influence of weather and other independent variables on energy use, whereas simple utility bill comparison techniques cannot. The analysis requires an evaluation of the behavior of the facility as it relates to one or more independent variables (e.g., weather, occupancy, production rate) using regression analysis.

4.4.2 Data Collection

Collecting, validating, and properly applying data are important elements of using utility or metered data analysis. Option C techniques use three types of data: utility billing data or other metered data, independent variables, and information on unrelated changes at the site. These data sources are discussed below.

4.4.2.1 Utility or Metered Data

Utility or metered data provide the basis for savings calculations by allowing a comparison of adjusted baseline models with performance period energy use. Regardless of the type of data used, a key to properly applying the data is ensuring that all start and end dates of the data are aligned with those of the independent variables. Collecting data on independent variables more often than collecting metered data can help align time frames. Metered data include the following.

- Monthly billing data. Billing data are usually available at monthly intervals. There are typically two types of monthly billing data: total use for the month and use aggregated by time-of-use periods. Although either type of data can be used with a regression model, time-of-use is preferable because it provides more insight into use patterns. In many cases, the peak demand is also recorded.
- Interval demand billing data. This type of billing data records the average demand (or energy use) for a given interval (e.g., 15 minutes) associated with the billing period and typically includes peak demand charges. For baseline model development, it is often useful to aggregate interval data on a daily or monthly basis.
- Stored energy billing data. Inventory readings or delivery information can be used to determine historical consumption for resources such as fuel oil, although submetering is preferred.
- Other metered data. Some buildings may have data available from meters not associated with the utility. Temporary meters may also be installed for baseline development.

4.4.2.2 Site Changes

A major challenge in applying Option C is accounting for factors beyond the ECM that affect overall site energy use, such as changes in square footage or loads. Tracking site changes provides a means for accounting for changes in energy use not associated with ECM installation. Adequately tracking the information needed to make these nonroutine baseline adjustments can be a challenging task and can increase the cost of performing M&V.

4.4.3 M&V Considerations[6]

The following points should be considered when conducting Option C utility data analyses for M&V.

- All independent variables that affect energy consumption must be specified, whether or not they are accounted for in the model. Critical variables can include weather, building occupancy, set points, time of day, number of meals served, etc. The most common variable for many types of ECMs is outdoor air temperature.
- The form and content of any separate performance period models (if used) should be specified, along with the statistical validation targets. Statistical validity of the final regression models must be demonstrated.

[6] See ASHRAE Guideline 14-2015, IPMVP Volume 1 (EVO 10000-1.2012) for additional information on utility billing analysis, and the IPMVP volume on Statistics and Uncertainty for IPMVP (EVO 10100-1:2014).

- Independent variable data must correspond to the time periods of the billing meter reading dates and intervals. A plan for data collection, including sources and frequencies, should be specified.
- It is best to develop models using data in whole-year sets (12, 24, 36, or 48 months) so that any seasonal variations are not overstated.
- It is necessary to specify how site changes unrelated to the installation of the ECMs will be tracked over the performance period and how these data will be used to perform savings adjustments.
- If baseline energy use needs to be adjusted to incorporate minimum energy or operating standards (such as minimum ventilation rates or lighting levels), any modification to the model needs to be detailed.

4.5 OPTION D—CALIBRATED SIMULATION

Option D involves whole facility or system analysis procedures to verify the performance of retrofit projects using calibrated computer simulation models. Computer simulation is a powerful tool that allows an experienced user to model the building and mechanical systems in order to predict building energy use both before and after the installation of ECMs. The accuracy of the models is ensured by using metered site data to describe baseline and/or performance period conditions. Carefully constructed models can provide savings estimates for the individual ECMs on a project. More elaborate models generally improve the accuracy of savings calculations but increase costs. A calibrated simulation of a building, however, can be used to easily evaluate savings from other potential improvements.

Building simulation requires experienced, qualified analysts; therefore, Option D methods should be used only for projects that meet any or all of the following requirements/characteristics.

- When projects are complex with too many ECMs to cost-effectively use retrofit isolation methods A or B
- When interactive effects between ECMs are too complex for retrofit isolation approaches but need to be quantified
- When complex baseline adjustments are expected during the performance period
- When energy savings values per individual measure are desired
- When new construction projects are involved
- When savings levels are sufficient to warrant the cost of simulation
- When either baseline or performance period energy data, but not both, are unavailable or unreliable

Option D is especially useful where a baseline does not exist (e.g., new construction or major building modification) or the factors responsible for savings are not easily measured (e.g., reduced solar gain and heat loss through new windows).

Situations for which computer simulation is not appropriate include the following.

- Analysis of ECM savings that can be more cost-effectively determined with other methods
- Buildings or building systems that cannot be adequately modeled such as those with complex geometries or other unusual features
- ECMs that cannot be adequately modeled such as radiant barriers or demand-response control algorithms that are important in comparing baseline and performance period scenarios
- Projects with limited resources that are not sufficient to support the effort required for data collection, simulation, calibration, and documentation

Even for the simplest projects, simulation modeling and calibration are time-intensive activities and should be performed by an accomplished building simulation specialist. Calibrated simulation analysis is an expensive M&V procedure and should be undertaken only on projects that generate enough savings to justify its use.

4.5.1 Approach to Option D

M&V Option D for an existing building typically follows five general steps: (1) collect data, (2) input data and test baseline model, (3) calibrate the baseline model, (4) create and refine the performance period model, and (5) verify performance and calculate savings. Each of these steps is discussed in detail below.

The method followed for new construction projects is somewhat different and is detailed in IPMVP Volume III.[7] One primary difference between the methods used for existing and new buildings is the availability of utility data. In new construction, the performance period model would be calibrated to utility data, whereas the baseline model would not due to lack of data, although comparisons with similar buildings can be made. This approach would also apply to an existing building that does not have reliable baseline energy data.

4.5.1.1 Collecting the Data

The data required for simulating an existing building can be voluminous, and ensuring collection of all data required to develop the simulation models is key. Collecting comprehensive baseline data is advised. All data collected do not necessarily need to be incorporated into the model but may be included to meet specific model accuracy requirements. All collected information and inputs need to be documented in a format that allows due-diligence review. Inadequate, disorganized, self-contradictory, or conflicting documentation can be grounds for rejecting a submittal.

To obtain end-use data for model calibration, building subsystem metering must be included in the project M&V activities for the baseline and performance periods. The specific subsystems selected for monitoring are in most cases the installed ECMs and related systems. For ECMs

[7] International Performance Measurements and Verification Protocol: Concepts and Options for Determining Energy Savings in New Construction, Volume III (EVO 30000-1.2006).

such as windows or insulation that cannot be monitored, the affected HVAC system should be submetered. The model calibration will benefit the most from monitoring the energy end uses for which the least information is available.

Required data typically include the following.

- Utility bill records. Collect a minimum of 12 (and preferably 24, 36, or 48) consecutive months of utility bills for the months immediately before installation of the ECMs. The billing data should include meter read date, kilowatt-hour consumption, peak electric demand, and heating fuel use (e.g., natural gas). Additional data in hourly and 15-minute formats may be required.
- Architectural, mechanical, and electrical drawings. As-built drawings are preferred.
- Site survey data. Comprehensive equipment and system data, typically collected during an audit, including the following.
  - HVAC systems, primary equipment (e.g., chillers and boilers): capacities, number, model and serial numbers, age, condition, operating schedules, etc.
  - HVAC systems, secondary equipment (e.g., air-handling units, terminal boxes): characteristics, fan sizes and types, motor sizes and efficiencies, design-flow rates and static pressures, duct-system types, economizer operation, and type of controls
  - HVAC system controls, including location of zones, temperature set-points, control set-points and schedules, and any special control sequences
  - Lighting systems: number and types of lamps, with nameplate data for lamps and ballasts, lighting schedules, etc.
  - Building occupants: population counts, occupation schedules in different zones
  - Other major energy-consuming loads: type (industrial process, air compressors, water heaters, elevators), energy consumption, schedules of operation

  Site survey data that may be required in addition to data normally collected during an audit include the following.

  - Plug loads: summarize major and typical plug loads for assigning values per zone
  - Building envelope and thermal mass: dimensions and type of interior and exterior walls, properties of windows, and building orientation and shading from nearby objects. Infiltration rates are important, but are often difficult to determine
  - HVAC systems: ventilation airflow rates can have a dramatic effect on energy use
- Short-term monitoring. The building energy management control system (EMCS) or data-logging equipment is set up to record system data over time. Typically, primary energy using systems and equipment involved in an ECM are monitored. These data may be required if particular subsystems (e.g., the chiller plant) need to be accurately modeled to determine savings. The data reveal how variable loads change with building operating conditions such as weather, occupancy, daily schedules, etc.
- Spot measurements of specific equipment. The power draw on lighting, plug load, HVAC equipment, and other circuits should be recorded to determine actual equipment operating powers.

- Operator interviews. Building operators can provide much of the above listed information and also information on deviations from the intended operation of building equipment.
- Weather data. For calibration purposes, representative site weather data are required for the period in question, as outlined in Section 4.5.3.1.
- Minimum code performance standards. For new construction projects and major renovations, minimum performance standards are often mandated for the baseline based on required codes.[8] If standards must be referenced in the baseline model, the minimum equipment efficiencies to meet the standards should be used.

4.5.1.2 Inputting the Data and Running the Baseline Model

The data must be adapted as required to the baseline model and entered into the simulation program input files. Key data for inclusion are physical properties of the facility, equipment and system types and efficiencies, appropriate weather data, and control sequences. Specific attention should be given to systems that will be modified by ECMs.

The more site-specific data incorporated, the more accurate the savings calculations but the greater the costs. The simulation program's user guide and other resources should be consulted as needed to determine how to properly input the collected data into the model. Based on the volume of data collected, many decisions must be made to best represent the data in the simulation program's input file. This can be done most cost-effectively by an experienced building modeling specialist.

After the data have been input, a few simulations should be run to debug the model, and the model output files should be checked to verify that there are no errors in the program. The following are some of the things to check.

- Does the HVAC system satisfy the heating and cooling loads?
- Are the equipment schedules correct?
- Are equipment efficiencies accurate?
- Are the model predictions reasonable?

4.5.1.3 Calibrating the Baseline Model

The baseline simulation model should be calibrated using the procedures described in Section 4.5.3 by comparing the energy use and demand projected by the model with the use and demand of the measured data from the utility or other meters. For new construction projects, the baseline energy use should be compared to other buildings that have similar operation and function. If required tolerances for the measured data are not met, the input data to the model should be refined until requirements are met.

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[8] Minimum efficiency standards include CA Title 24, ASHRAE 90.1, IECC, and state energy codes.

The calibrated model should be documented by showing final input parameters for the model. This information, as well as the actual calibration results, needs to be provided in the M&V submittals.

4.5.1.4 Creating and Refining the Performance Period Model

Starting with the calibrated baseline model, the model should be updated to include the building's ECMs to create the performance period model.

If individual savings levels from each ECM are desired, an approach that includes the interactive effects of the ECMs is to input the ECMs consecutively into the baseline model. Some software allows the modeler to create a rolling baseline by including the previous ECMs in the model. After each ECM has been modeled, the simulation is run. The first run is the baseline model, the second run is ECM 1, the third run is ECM 1 and ECM 2, the fourth run is ECM 1, ECM 2, and ECM 3, etc. After the final ECM has been input, the model should represent the performance period condition with all ECMs installed. This approach includes interactive effects in the savings for each ECM.

Determining the sequence in which to input each ECM into the model is an important consideration in managing interactive effects. Typically measures that will affect the overall heating and cooling loads of the building (e.g., envelope improvements or lighting upgrades) should be input first. Secondary ECMs are those that affect the HVAC subsystems, and the last ECMs that should be input are those affecting the central plant.

Some simulation programs run each ECM against the original baseline, which neglects any interactive effects between the measures. These intermediate results are not always 100% additive, as two ECMs that save 2% alone, may not save 4% combined. Considering the interactive effects of ECMs, these ECMs combined may save 3%. When using this approach, a final run including all measures must be executed to determine the interactive effects of all the ECMs. This approach does not allocate interactive effects to the individual ECMs.

4.5.1.5 Verifying Performance and Calculating Savings

The method used to determine savings will depend upon the phase of the project. During project development, proposed savings are determined by subtracting the results of the performance period model from the results of the calibrated baseline model, using both the agreed-upon weather data and the facility operating conditions.

After the first year of performance there are two options to calculate verified savings:
(1) calibrate the performance period model and subtract the results from the baseline model using the same conditions or (2) subtract measured utility data for the performance period from the results of the baseline model that was updated to actual conditions.

The first option requires that the performance period model be calibrated using the procedures described in Section 4.5.3. Update the performance period model using data collected during the performance period from site surveys, spot measurements, short-term monitoring, and utility data. Effort can be minimized by focusing data collection on the installed ECMs.

If savings are to be estimated for a specific year, actual weather and other data from that year must be used. If savings are to be normalized to typical conditions, for example, then typical weather data (e.g., TMY data) should be used. In any case, both the baseline model and the performance period model must be run with the same weather data. The weather data to be used are specified in the site-specific M&V plan. Although time-intensive, Option D approaches are well suited to adjust models when significant site changes occur during the performance period.

If savings for each ECM are to be determined including interactive effects, the ECMs must be input consecutively into the model and simulations run after each input, as described previously.

Individual ECM savings are determined by the difference in energy or demand use between two consecutive runs. The savings determined for the individual ECMs should total the savings determined from the baseline and performance period runs. It is important that savings be determined with both models using the same conditions (weather, occupancy schedules, set points, etc.), except for the characteristics of the installed ECMs.

The energy values and rate structure specified in the M&V plan are applied to the energy savings determined by the model. If utility rates are included in the model, sufficient information on the savings should be provided so that cost calculations can be verified. When time-of-use charges or other variable use schedules are applied, the demand (kilowatts) and energy (kilowatt-hours) savings must be broken down into the proper categories to determine cost savings.

4.5.2 Simulation Software

The building energy simulation programs used most frequently for energy analyses are whole facility programs that create customized models of buildings and their systems and use hourly weather data to predict energy use. Such programs are very versatile, allowing the accurate modeling of most buildings through custom input data. Two of the most common public domain programs of this type are eQUEST and EnergyPlus.[9] A complete list of available energy simulation programs is maintained by the US Department of Energy (DOE).[10]

These building simulation programs require extensive input data to accurately model the energy use of a building. Recently, user interfaces have been improved that simplify the input process with graphical formats, and libraries of typical building components have been added to facilitate model development.

Simulation programs acceptable for Option D should have the following characteristics.[11]

- Commercially available, supported, and documented.
- Able to adequately model the project site and ECMs.
- Able to be calibrated to an acceptable level of accuracy.

[9] eQUEST is available through http://doe2.com/equest/ (current release is eQUEST 3.6 and 3.61b), and EnergyPlus is available through http://www.eere.energy.gov/buildings/energyplus/.

[10] See http://www.eere.energy.gov/buildings/tools_directory/subjects_sub.cfm.

[11] For more information on building simulation program elements, see ASHRAE 90.1-2013, *Energy Standard for Buildings Except Low-Rise Residential Buildings*, Section G.2, or ASHRAE Guideline 14-2015.

- Able to use actual weather data in hourly format.

4.5.3 Model Calibration[12]

Model calibration for existing buildings is accomplished by linking simulation inputs to actual operating conditions and comparing simulation results with whole building and/or end-use data. The simulation may be of a whole facility or just for the end use or system affected by the ECM. Both baseline and performance period models should be calibrated wherever possible. Model calibration is typically an iterative process of adjusting model inputs and recomparing the results to measured data. A model is considered in calibration when the statistical indices demonstrating calibration have been met. Expected calibration requirements should be specified in the project-specific M&V plan, and industry standard guidelines are included in Table 4-2. These requirements should be adjusted as required to meet the needs of the project.

Table 4-2. Acceptable Calibration Tolerances[a]

Calibration Type	Index	Acceptable Value[b]
Monthly	MBEmonth C_v(RMSEmonth)	± 5% 15%
Hourly	MBEmonth C_v(RMSEmonth)	±10 % 30%

[a]Data in this table taken from ASHRAE Guideline 14-2015, Section 5.3.3.3.10.
[b]Lower values indicate better calibration.
Acronyms: MBE = mean bias error, C_v = coefficient of variation, RMSE = root mean square error.

For most models, multiple levels of calibration, such as the following, can be performed.

- System level calibration with hourly monitored data
- Whole facility level calibration with monthly utility data
- Whole facility level calibration with hourly utility data

Determining the level of calibration that is needed depends on the value of the project, the availability of data, and the need for certainty in the savings estimates. All models should be calibrated to monthly data at a minimum. Simulation models that focus on specific systems should be calibrated to system level data. Also, calibrating the models to hourly data will help ensure accuracy, especially for determining peak demand savings. Calibrating a computer simulation to measured utility data necessitates that actual weather data be used, as discussed below.

The calibration procedures should apply to all sources of savings (demand, electricity, natural gas, etc.) but should focus on the primary ones. Each of these model calibration strategies is discussed below.

[12] See ASHRAE Guideline 14-2015 and IPMVP Volume 1 (EVO 10000-1.2012) for additional information on simulation modeling and validation techniques.

4.5.3.1 Weather Data

The first step in calibrating a model is updating and running the model using weather data that correspond precisely to the same calendar days as each utility bill. Programs that allow the use of only average weather files or weather data from only a few representative periods per month or per season are not suitable for the calibration techniques required for Option D.

Obtaining weather data for the appropriate location and time period is an important step in calibrating any simulation model. Several resources are available for getting real-time weather data and converting them into the proper format for use with the simulation software. DOE maintains a website that provides weather data from 1998 to the present from up to 4,000 weather stations.[13] Some data may be missing but can be interpolated from the DOE database.[14]

The database provides data in a format used by EnergyPlus, but the data can be converted for use with eQUEST and other programs.[15] Because using actual weather data can be time consuming, it is sometimes appropriate to modify average weather to more closely match the actual weather.[16]

The time period and frequency of the weather data need to align with the utility data periods, which can require data manipulation. The measure-specific M&V plan must specify which weather data sources will be used, including both the source of the data and the physical location of the weather station.

After the model has been calibrated using actual weather data, the building's energy use may be adjusted to average-year weather. Average weather data may be obtained from the National Renewable Energy Laboratory (TMY2, TMY3).[17]

4.5.3.2 Statistical Indices

For all of these approaches, two prescribed statistical indices (described below) must be calculated in order to declare a model calibrated: the mean bias error (MBE) and the coefficient of variation of the root mean square error [C_v(RMSE)].[18] The recommended calibration requirements are those specified by ASHRAE Guideline 14. Specific calibration goals should be set for each project based on appropriate level of effort. This process should be applied to electricity (kilowatt-hours), demand (kilowatts), and all other fuels used.

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[13] The DOE website is http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm.

[14] Detailed information on the data can be found in *Real-Time Weather Data Access Guide, User's Guide NREL/BR-550-34303, March 2006*, National Renewable Energy Laboratory, http://apps1.eere.energy.gov/buildings/energyplus/pdfs/weatherdata_guide_34303.pdf. The FAQs and instructions in the guide should be followed to fill in the missing data.

[15] Weather file converter software is available through http://doe2.com/index_Wth.html.

[16] See http://apps1.eere.energy.gov/buildings/energyplus/pdfs/bibliography /whichweatherdatashouldyouuseforenergysimulations.pdf?utm_source=EnergyPlus&utm_medium=redirect&utm_campaign=EnergyPlus%2Bredirect%2B1 for discussion of simulation issues.

[17] http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/.

[18] See ASHRAE Guideline 14-2015 and Section 4.2.2 for additional information.

In addition to statistical indices, graphical comparison techniques can be an effective tool for understanding the variances present in a model. Simple or advanced methods of graphical comparison techniques can be effective, and are detailed in ASHRAE Guideline 14.

As mentioned above, actual weather corresponding to the time period in question should be used in the model. Typically, the energy consumption predicted by the model and measured by the utility or submeter are determined for every month or interval in the data set, as well as for the whole year or period, and statistical analyses are performed on the results. The same techniques can be applied to hourly and subsystem data. The statistical values that need to be calculated are MBE and C_v(RMSE).

- MBE. MBE indicates how well the energy consumption is predicted by the model as compared to the measured data. Positive values indicate that the model overpredicts actual values; negative values indicate that the model underpredicts actual values. However, it is subject to cancellation errors, where the combination of positive and negative values serves to reduce MBE. To account for cancellation errors, the C_v(RMSE) is also needed.
- C_v(RMSE). This value indicates the overall uncertainty in the prediction of whole facility energy use. The lower the C_v(RMSE), the better the calibration. This value is always positive.

The mean bias error is calculated by subtracting the simulated energy consumption from the measured energy consumption for all the intervals over a given time period. The differences from each interval are summed and then divided by the sum of the measured energy consumption over the same time period. MBE calculation is expressed in Equation 4-1.

Equation 4-1. Measured Energy Consumption

$$MBE(\%) = \frac{\sum_{Period} (S-M)_{Interval}}{\sum_{Period} M_{Interval}} \times 100 ,$$

where

M is the measured kilowatt-hours or fuel consumption during the time interval,

S is the simulated kilowatt-hours or fuel consumption during the same time interval.

The C_v(RMSE) is a normalized measure of variability between two sets of data. For calibrated simulation purposes, it is obtained by squaring the difference between paired data points, summing the squared differences over each interval through the period, and then dividing by the number of points, which yields the mean squared error. The square root of this quantity yields the RMSE. The C_v(RMSE), is obtained by dividing the RMSE by the mean of the measured data for the period.

RMSE for the period is calculated using Equation 4-2.

Equation 4-2. Root Mean Square Error

$$RMSE_{Period} = \sqrt{\sum \frac{(S-M)_{Interval}^{2}}{N_{Interval}}},$$

where

$N_{Interval}$ are the number of time intervals in the monitoring period.

The mean of the measured data for the period is calculated using Equation 4-3.

Equation 4-3. Mean of the Measured Data

$$A_{Period} = \frac{\sum_{Period} M_{Interval}}{N_{Interval}}$$

The C_v(RMSE) is calculated using Equation 4-4.

Equation 4-4. Coefficient of Variation of the Root Mean Square Error

$$Cv(RMSE_{Period}) = \frac{RMSE_{Period}}{A_{Period}} \times 100$$

The primary differences in applying these indices to the various data sets (monthly, hourly, submetered) are (1) the acceptable values of the indices and (2) the definition of “interval” and “period” in each of the equations above. The application of these statistical indices for each level of calibration is detailed in the sections below.

The recommended acceptable values for each approach are included in Table 4-2. These values have been adopted from ASHRAE Guideline 14. Specific calibration goals should be set for each project based on the appropriate level of effort and should be specified in the project-specific M&V plan.

4.5.3.3 Subsystem Level Calibration with Monitored Data

Calibration of building model subsystems to measured data may be required to enhance accuracy or ensure the overall accuracy of the model meets specified targets. The hourly energy use (kilowatt-hours, therms, or British thermal units) predicted by the model is compared against measured hourly energy use for the monitored building subsystems to determine whether the model accurately predicts subsystem level use.

Most simulation programs, including eQUEST, output subsystem use values minimally in 1-hour intervals. Therefore, for calibration, measured data must be averaged over each hour. For example, if 15-minute chiller demand (kilowatts) data are collected, they must be averaged into hourly values.

When applying the statistical equations above to submetered data, the interval is an hour, and the period can be defined by the user.

4.5.3.4 Whole Facility Level Calibration with Monthly Data

Comparing energy use projected by the building model with monthly utility bills is the minimum level of calibration that should be conducted on any model of an existing building with monthly utility data available. In the statistical equations above, the interval is a month and the period is a year.

4.5.3.5 Whole Facility Level Calibration with Hourly Data

When hourly data are applied, the interval is an hour and the period can be defined by the user, and often a 1-month billing period is used. These indices, however, may be calculated for the entire period or for weekdays, weekends, and holidays separately.[19]

4.5.4 M&V Considerations

Many issues must be considered and addressed in developing a project-specific M&V plan using Option D. Some of the more common steps are outlined below.

- Use an experienced building modeling professional. Although new simulation software packages make much of the process easier, a program's capabilities and real data requirements cannot be fully understood by inexperienced users, and resulting models may not be accurate.
- Determine the availability of utility bill data.
- Determine whether hourly or monthly billing data are available and whether meters can be installed to collect hourly data. Calibrations to hourly data are generally more accurate than calibrations to monthly data because there are more points to compare. Hourly energy or demand data, however, are generally only available for a utility's largest customers or may be collected with portable data loggers. If only monthly billing data are available, conducting additional short-term monitoring of building subsystems can improve the accuracy of the model.
- Use actual equipment performance data in the simulation models. Many software packages have libraries of HVAC equipment that closely match actual system performance. Be cautious and investigate the library HVAC description to be sure it is a good representation of the real system and consider developing user-defined equipment performance curves based on field measurements or manufacturers' data.
- Specify spot measurements and short-term monitoring of key parameters for both the baseline and performance period models. Spot and short-term measurements augment whole facility data and more accurately characterize building systems. It is recommended that an end use be monitored over a period that captures the full range of the equipment's operation (e.g., spring and summer for cooling systems. The data must also be collected in a way that

[19] Bou-Saada, T. E., and J. S. Haberl, *An Improved Procedure for Developing Calibrated Hourly Simulation Models,* International Building Performance Simulation Association, Report No. ESL-PA-95/08-01, 1995.

facilitates subsystem level calibration. Careful selection of spot measurements and short-term monitoring is necessary because it can add significant cost and time to the project.

- Use trend data to determine actual controls. Sequencing of building controls is difficult to interpret from interviews, site surveys, manufacturers' data, and spot measurements. The best way to ascertain actual sequences is through trending data. Sometimes, the EMCS systems can be used to determine actual operating scenarios. However, the capability for data storage in many systems may be limited.
- Specify model calibration procedures that will be followed for monthly, hourly, or subsystem data for both the baseline and performance period models. Prescribe statistical calibration requirements based on the accuracy required for the project.
- Specify the simulation program and version and the source of weather data used (on-site, local weather station or typical weather data).
- Clearly explain how savings will be calculated after the first year. Keeping models up to date can be expensive. For projects without substantial site changes expected, an Option C utility billing analysis approach may be viable. Regardless of how savings are calculated each year, the ongoing performance of the measures needs to be verified periodically.

SECTION 5. SELECTING AN M&V APPROACH

The appropriate level of measurement and verification (M&V) rigor and accuracy is a level that protects the project investment and fulfills the intent of the contract between the ESCO and the customer. Careful consideration of the M&V level, type, and rigor benefits both parties and can help mitigate potential problems.

In general, the selection of an M&V method is based upon the following.

- Project costs and expected savings
- Complexity of the energy or water conservation measures (ECMs)
- Number of interrelated ECMs at a single facility
- Uncertainty or risk of savings being achieved
- Other uses for M&V data and systems

This section discusses these issues, presents some rules of thumb to use when selecting an M&V approach, and discusses a method for evaluating project-specific M&V options. Additional discussion is provided on balancing M&V costs and technical rigor, as well as tips on minimizing uncertainty in the savings results.

5.1 KEY ISSUES IN SELECTING THE APPROPRIATE M&V APPROACH

The level of certainty and thus effort required to verify both a project's potential to perform and its actual performance will vary from project to project. The project-specific M&V plan should be prepared with serious consideration of what M&V requirements, reviews, and costs will be specified. Some key factors, outlined below, should be considered when choosing the M&V options and techniques to use for each project.

5.1.1 Value of ECM in Terms of Projected Savings and Project Costs

The scale of a project, energy rates, term of the contract, comprehensiveness of ECMs, benefit-sharing arrangement, and magnitude of savings can all affect the value of the ECM. The M&V effort should be scaled to the value of the project so that the value of the information provided by the M&V activity is appropriate to the value of the ECM and the project itself.

For federal ESPC projects, average annual M&V costs currently range from about 2%–5% of annual project cost savings. Some more complex ECMs will often warrant greater M&V costs, but the overall M&V costs for the project are typically balanced by other ECMs that do not require substantial annual activities.

5.1.2 Complexity of ECM or System

More complex projects may require more complex (and thus more expensive) M&V methods to determine energy savings. In general, the complexity of isolating the savings is the critical factor.

For example, a complicated chiller measure may not be difficult to assess if there are energy submeters and monitoring systems dedicated to the chiller system.

When defining the appropriate M&V requirements for a given project, it is helpful to consider ECMs as being in one of the following categories (listed in order of increasing M&V complexity).

- Constant load, constant operating hours
- Constant load, variable operating hours
- Variable load, variable operating hours

5.1.3 Number of Interrelated ECMs at a Single Facility

If multiple ECMs are being installed at a single site, the savings from each measure may be, to some degree, related to the savings resulting from other measures or other non-ECM activities at the facility. Examples include interactive effects between lighting and heating, ventilation, and air conditioning measures or between envelope improvements and a chiller replacement. In these situations, it may not be possible to isolate and measure one system to determine savings. Thus, for multiple, interrelated measures, whole facility Options C or D may be the most appropriate.

5.1.4 Risk of Achieving Savings

The importance of the M&V activities is often tied to the confidence associated with the estimated energy or cost savings. An ECM with which the facility staff is familiar may, subjectively, require less M&V rigor than ECMs that are less well known. Similarly, unproven technologies may warrant additional attention.

A simple method of estimating payment risk can be based on the estimated project value, technical uncertainty, and project sponsor experience. Such a method assumes that, as a starting point, all projects will be inspected to verify the project's potential to perform and estimate savings uncertainty and payment risk. A simple illustration of this method is shown in Table 5-1.

Table 5-1. Example Estimate of Savings Risk

Sample Project	Estimated Savings	Estimated Uncertainty	Savings Risk
Small lighting	$50,000	10%	$5,000
Large custom	$500,000	20%	$100,000

A limit on the M&V budget can then be established as a percentage of the project's payment risk before an M&V plan is specified. As illustrated, smaller projects consisting of predictable technologies have less savings risk (and thus a lower M&V budget cap) than large projects that include less predictable technologies.

In the same example, for the "large custom" measure, two M&V approaches may be evaluated based on their benefit-to-cost ratio, as indicated Table 5-2. In this example M&V Option C appears to be the better approach.

Table 5-2. Example Benefit-to-Cost Evaluation for Measurement and Verification (M&V)

Sample Project	Estimated Savings	Estimated Uncertainty (No M&V)	Savings Risk (No M&V)	Proposed M&V Method	Estimated Annual M&V Cost	Resulting Savings Uncertainty/ Savings Risk	Benefit-to-Cost Ratio: Risk Reduction in Savings/M&V Cost
Large custom	$500,000	20%	$100,000	Option C	$25,000	10%/$50K	2.0
Large custom	$500,000	20%	$100,000	Option B	$50,000	8%/$40 K	1.2

5.1.4.1 Other Uses for M&V Data and Systems

Often, the array of instrumentation installed and the measurements collected for M&V can be used for other purposes, including commissioning, system optimization, and periodic recommissioning during the performance period. Data and systems are more cost-effective if they are used to meet several objectives, and not just those of the M&V plan. In addition, savings could be quantified beyond the requirements of the performance contract. This information could be useful for allocating costs among different tenants, planning future projects, or allocating research.

5.2 COST AND RIGOR

In general, the more rigorous the M&V, the more expensive it will be to determine energy savings. The factors that typically affect M&V accuracy and costs (some are interrelated) are listed below.

- Level of detail and effort associated with verifying baseline and performance period surveys
- Sample sizes (number of data points) used for metering representative equipment
- Duration and accuracy of metering activities
- Number and complexity of dependent and independent variables that are metered or accounted for in analyses
- Level of engineering required to conduct analyses
- Availability of existing data collecting systems (e.g., energy management systems)
- Contract term (in performance-based contracts)
- Level of accuracy needed in energy savings analyses

5.2.1 Balancing Cost and Rigor

One of the most challenging aspects of M&V is providing adequate accuracy while ensuring that M&V costs are reasonable. As shown in Figure 5-1, the incremental value of the information obtained from additional M&V will at some point be less than the cost to obtain it.

Unfortunately, there is no easy way to define this point and one must rely upon judgment and experience to determine what is cost-effective and what is not.

The following are a few strategies for holding costs down while maintaining technical rigor.

- Use extensive metering in the baseline period and stipulate values over which the energy service company (ESCO) has no control.
- Verify key performance items using periodic rather than continuous data collection to reduce data collection and management issues.
- Rely upon existing instrumentation, energy management systems, and energy management behavioral practices wherever possible.
- Engage a third-party M&V expert to assist in development of the M&V plan to ensure key customer interests are protected and costs are minimized.

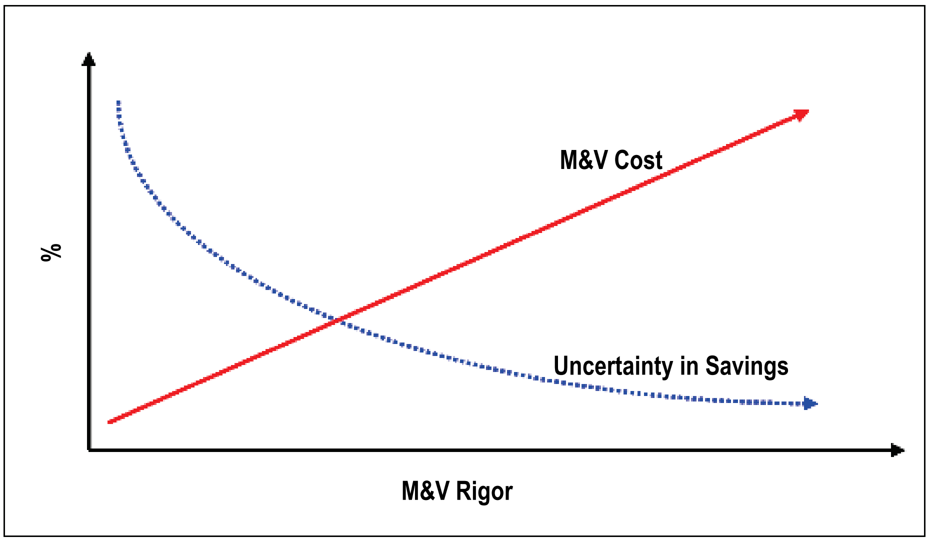

Figure 5-1. The Law of Diminishing Returns for Measurement and Verification (M&V).

5.2.2 M&V Costs

The M&V effort should be scaled to the value of the project so that the value of the information provided by the M&V activity is appropriate to the value of the project itself. Rule-of-thumb estimates put overall annual M&V costs at 2% to 5% of typical annual project cost savings. Often, some ECMs will entail greater M&V costs, but the overall M&V costs for the project are balanced by other ECMs that do not require substantial annual activities.

5.3 UNCERTAINTY

Any statement of measured savings, such as energy savings, includes some degree of uncertainty. A goal for each project is to balance the uncertainty in the reported savings values with the cost of M&V. Reductions in uncertainty are obtained by limiting errors in the measurements and analyses conducted.

Calculating the uncertainty in the estimated savings is not required for federal projects, but this uncertainty is often estimated to set the overall level of savings guarantee for each ECM.

Including the uncertainty in calculated savings values provides a more meaningful statement of savings. Uncertainty is typically proportional to the complexity of the ECM.

Uncertainty at the project level can be broken down into four general types: measurement, sampling, estimation, and modeling. For any given project, the project error is calculated from these four uncertainties. Frequently projects do not contain all of the four components; however, in a hypothetical project that contains all four components, the total project uncertainty (standard error) would be calculated by taking the square root of the sum of the squares of the individual standard errors of the components:

$$SE_{Project} = \sqrt{(SE_{Measurement})^2 + (SE_{Sampling})^2 + (SE_{Estimation})^2 + (SE_{Modeling})^2} \quad .$$

The following sections discuss the sources of these errors and the ways that these errors can be minimized.[20]

5.3.1 Measurement

Measurement uncertainty is due to metering equipment inaccuracies. For example, the specifications for a meter may indicate that it is accurate to within ± 5%, meaning that any reading taken with the meter may be up to 5% off in either direction. Additional error in measurements may be introduced if an instrument is not properly calibrated or if it is applied under inappropriate conditions. Data management can also introduce errors through omitted, adjusted, or lost data.

For an M&V plan to be successful, the instruments used for baseline and performance period measurements must meet minimum accuracy requirements for the application and must be properly calibrated. If the accuracy of any instrument is less than suitable, the measurements may introduce unacceptable levels of error into the energy calculations.

Instrumentation accuracy requirements should be sufficient to ensure that overall energy and cost estimates are reasonable. Although error analysis is not required for federal projects, it is important to keep in mind that the inaccuracies introduced by the instrumentation will likely be the greatest source of uncertainty in calculated savings.

For example, in a chiller project it is often necessary to measure efficiency in kW/ton. The capacity in tons is determined by measuring the flow rate and temperature differential across the chiller, and the power in kW is measured using an electrical meter. Figure 5-2 shows the percentage error in calculating kW/ton efficiency as a function of the measured temperature differential for various levels of temperature sensor accuracy (given a ± 5% error in flow measurement and a ± 2% error in in power measurement).

[20] Additional information on these topics is contained in ASHRAE Guideline 14 Section 5.2.11 and the IPMVP volume on Statistics and Uncertainty for IPMVP (EVO-10100-1:2014).

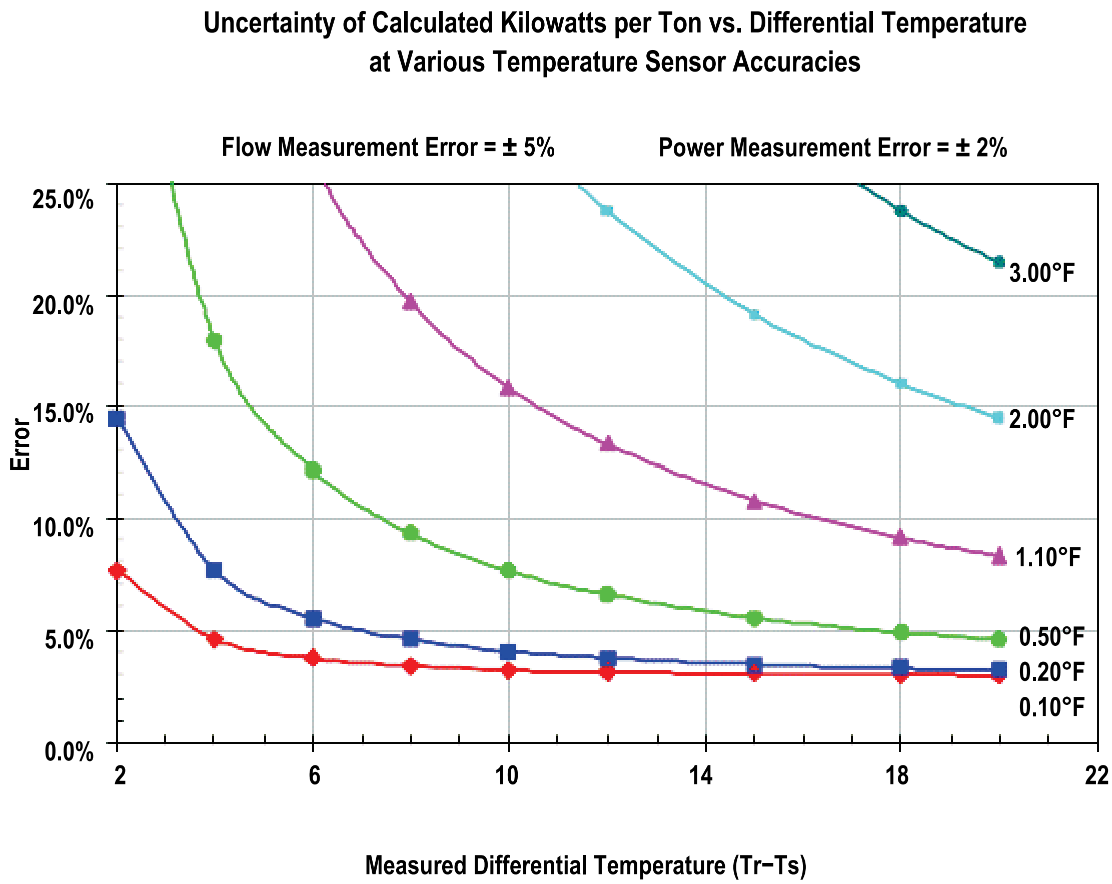

Figure 5-2. Example Influence of Sensor Accuracy on Calculations.[21]

The following are tips for reducing measurement errors.

- Determine and prescribe the needed accuracy for measurement equipment.
- Ensure that the measurement equipment has been recently calibrated.
- Specify data management strategies, including periodic checks and backup procedures.
- Ensure that instrumentation is installed correctly per manufacturer specifications.

5.3.2 Sampling

Sampling uncertainty occurs when measurements are taken on a sample of the affected equipment and the results extrapolated to the entire population of the equipment. For example, it may not be economically feasible to monitor the hours on every fixture in a building lighting retrofit. Often, a sample is monitored, and the results applied to the remainder of the lighting population. Sampling uncertainty is calculated from the standard deviation of the sampled results. When the standard deviation is large, the uncertainty is also large. A detailed discussion on sampling can be found in the IPMVP volume on Statistics and Uncertainty[22]

[21] Analysis provided by Scott Judson, Director of Performance Engineering, NORESCO.

[22] International Performance Measurement and Verification Protocol: Statistics and Uncertainty for IPMVP, EVO-

The following are tips for reducing sampling errors.

- Assign homogeneous usage groups based on similarities in equipment performance or operating characteristics.
- Use statistical sampling strategies as described in the IPMVP volume on Statistics and Uncertainty.
- Use sample sizes that meet a confidence level of at least 80% and a precision of 20%.
- Ensure that the measured data meet statistical requirements by calculating the actual coefficient of variation (C_v) from the measurements.
- Use a conservative approach in selecting original sample sizes by using a high C_v, typically greater than 0.5, especially for populations that are known to contain variations. This will increase the initial sample size, but reduce the risk of under-sampling.

5.3.3 Estimating

Estimates have to be made when values are necessary to complete a calculation, but the values cannot be measured directly. When engineering estimates are used in lieu of actual measurements, uncertainty is introduced. This uncertainty itself must often be estimated based on the expected accuracy of the estimated values. For example, the efficiency of a boiler may be estimated rather than measured directly. The estimate would be based on the type and age of the boiler, and may result in an estimated stipulation error of ± 20% (e.g., 75%, between 60% and 90%). If a building engineer who is familiar with the boiler gives additional operational information about the boiler, the uncertainty may be less, such as ± 10% (e.g., 75%, between 67.5% and 82.5%).

The following are tips for reducing estimating errors.

- Use measured values wherever possible, especially for parameters that contribute to a high percentage of project savings.
- Use the manufacturer's original specifications or industry-accepted performance curves to determine performance.
- Use typical meteorological year weather data[23] from an applicable site to conduct calculations.
- Use observations of building occupant behavior and facility operating and maintenance logs.
- DO NOT use rules of thumb, proprietary software/algorithms, guesses at operating parameters, or data from other facilities.

10100-1.2014, Efficiency Valuation Organization.

[23] Typical meteorological year weather data are available from the National Renewable Energy Laboratory (http://www.nrel.gov/news/press/2008/594.html).

5.3.4 Modeling

Modeling uncertainty is introduced when savings are estimated using engineering or simulation models. The accuracy of any model is based on the ability of the model to account for all variations in energy use by employing the proper analysis techniques, including all relevant variables, and excluding those that are irrelevant.

SECTION 6. GUIDANCE FOR SPECIFIC ECMs

6.1 INTRODUCTION

This section provides general M&V guidelines for standard ECMs typically implemented under performance contracts and other conservation projects. It contains procedures and guidelines for quantifying the savings resulting from energy efficiency equipment, water conservation, and renewable energy projects. The emphasis is on key parameters that should be considered when performing M&V on specific ECMs. Of course, site-specific variations must be considered as well when developing an M&V plan. The material presented in this section is general in approach and will provide an idea of the general approach to most ECMs. In reality, an M&V plan must be tailored to a specific ECM at a specific site. The guidance in this section is a broad approach for general ECMs, and the outlines provided do not consider ECM size, cost, and savings, which are crucial for development of proper M&V plans. The existence of multiple different ECMs in a single building may also affect the choice of M&V technique.

These outlines were adapted from techniques developed for the US Department of Veterans Affairs.

6.2 ECM: LIGHTING

6.2.1 M&V Option A

This measure involves the implementation of high efficiency lighting with higher efficacy (lumens per watt) values over the existing lighting at the facility. This measure includes the upgrade of lamps, fixtures, lenses, reflectors, and ballasts that will maximize savings while maintaining proper lighting levels.

6.2.1.1 M&V Plan Description

Option A (Retrofit Isolation with Key Parameter Measurement) will be used to quantify the energy consumption savings associated with the lighting upgrades.

6.2.1.2 M&V Option Selection Rationale

- Lighting retrofit projects are considered simple savings measures that require a small number of measurements to verify savings. Lighting upgrade savings are typically easy to quantify and verify during the baseline, post-installation, and performance periods. Typical lamp and ballast combination lighting tables may be used to verify fixture power.
- Depending on customer preference, performance parameters (Table 6-1) may be measured during the performance period or may be based on post-installation measurements taken during commissioning.

Table 6-1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Lighting Power (kW)			
Performance	Baseline	10% precision with 90% confidence or 20% precision with 80% confidence	Spot measurement
Performance	Post-Installation	10% precision with 90% confidence or 20% precision with 80% confidence	Spot measurement
Performance	Performance	Verified at commissioning (one time or continuous, depending on savings)	None or periodically depending on savings
Lighting Levels (foot-candles/lumens)			
Performance	Baseline	10% precision with 90% confidence or 20% precision with 80% confidence	Spot measurement
Performance	Post-Installation	10% precision with 90% confidence or 20% precision with 80% confidence	Spot measurement
Performance	Performance	Verified at commissioning (one time or continuous, depending on savings)	None
Lighting Run Time (hours per location)			
Operation	Baseline	10% Precision with 90% confidence or 20% precision with 80% confidence	Short-term metering
Operation	Post-Installation	Measured during baseline period	Stipulated
Operation	Performance	Measured during baseline period	Stipulated

- Baseline and post-installation performance parameters for a sample set of fixtures (power level of lamp and ballast combinations) will be spot measured. It is recommended to spot measure the more typical or larger group of lamps being installed over the small groups of lamps being installed. Ideally, fixtures that represent at least 75% of the lighting energy use will be measured.
- Baseline operational parameters (hours of operation of the lighting system) will be verified via short-term data logging. It is recommended to focus on typical spaces that represent the largest areas in the facility. Ideally, spaces that represent at least 80% of the lighting energy use will be measured.
- Baseline and post-installation lighting levels will be verified by spot measurements in about 20% of the spaces. It is required that the lighting levels meet the customer’s lighting design illumination levels.
- Calculations of savings should consider heating/cooling load impacts.

6.2.1.3 M&V Performance Assurance Activities

- Confirm that installed lamps, fixtures, and ballasts were installed as stated in the scope of work and are performing as specified.
- As required, perform annual sample set measurements of fixture kilowatt-hours of operation and average foot-candles for the area.

- Obtain approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.3 ECM: LIGHTING CONTROLS

6.3.1 M&V Option A

This ECM involves installing controls on the existing lighting systems to reduce run hours through implementation of occupancy sensors, day lighting controls, and improved programmed run times.

6.3.1.1 M&V Plan Description

Option A (Retrofit Isolation with Key Parameter Measurement) will be used to quantify the energy consumption savings associated with the lighting controls. The lighting retrofit may consist of installation of new lighting controls that will reduce run times through standard lighting measures. Fixture power measurement procedures will be identical to that outlined in the lighting ECM (Section 6.2).

6.3.1.2 M&V Option Selection Rationale

- Implementation of lighting controls is a proven technology. It is easy to capture and quantify the changes in performance and operational parameters needed to calculate energy savings.
- Performance parameters (Table 6-2) can be spot measured via a sampling plan. Operational parameters will be verified via short-term data logging.
- Baseline and post-installation performance parameters for a sample set of fixtures (power level of lamp and ballast combinations) will be spot measured during the baseline development and post-installation period.
- Baseline and post-installation operational parameters (hours of operation of the lighting system) will be verified via short-term data logging conducted during the baseline development and commissioning. The baseline coefficient of variation (C_v; no controls) is assumed to be 0.5. For post-installation measurements, the C_v is assumed to be 1.0 for spaces controlled by motion sensors and 0.5 for all other controls.

Table 6-2. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Lighting Power (kW)			
Performance	Baseline	10% precision with 90% confidence or 20% precision with 80% confidence	Spot measurement
Performance	Post-Installation	10% precision with 90% confidence or 20% precision with 80% confidence (If fixture power changes due to retrofit; no measurement required otherwise.)	Spot measurement
Performance	Performance	Verified at commissioning	None

Table 6-2. M&V Plan Performance and Operational Parameters (continued)

Parameter	Period	Population	Measurement
Lighting Levels (foot-candles/lumens)			
Performance	Baseline	Day lighting only	Spot measurement
Performance	Post-Installation	Day lighting only	Spot measurement
Performance	Performance	Verified at commissioning (one time or continuous).	None
Lighting Run Time (hours per location)			
Operation	Baseline	10% precision with 90% confidence or 20% precision with 80% confidence	Short-term metering
Operation	Post-Installation	10% precision with 90% confidence or 20% precision with 80% confidence	Short-term metering
Operation	Performance	Measured during baseline period (one time or continuous).	None

- One-time baseline and post-installation lighting levels will be verified by spot measurements in about 20% of the spaces incorporated with day lighting controls. Lighting levels should not fall below customer's lighting design criteria.

6.3.1.3 M&V Performance Assurance Activities

- Confirm that installed occupancy sensors and day lighting controls were installed as stated in the scope of work and are performing as specified.
- Confirm that the proposed lighting schedule changes have been properly programmed and that the lighting schedule is maintained as operational over the term of the project.
- Perform post-installation sample set measurements of fixture kilowatts and average foot-candles for the area.
- Perform annual facility walk-through inspection of the control panels to verify programming.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.4 ECM: BUILDING ENVELOPE IMPROVEMENTS

6.4.1 M&V Option D

This measure involves upgrading the building envelope to reduce heat transfer and/or infiltration.

6.4.1.1 M&V Plan Description

Option D (Calibrated Simulation) will be used to quantify the energy consumption savings associated with improved building envelope. Option D will be used during the performance period of the contract.

6.4.1.2 M&V Option Selection Rationale

- The overall savings associated with this measure can be calculated using a calibrated building energy analysis model meeting the requirements of American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Standard 90.1 Appendix G. The baseline model is calibrated to utility bills or short-term metered data.
- Option D is recommended for ongoing verification of the performance of this ECM.
- The performance parameters (Table 6-3) include the calculation of the envelope U-value using ASHRAE 90.1 standards. The U-value will need to be calculated based on building construction found during the baseline development and commissioning. These values will be the parameters used within the model to calculate energy savings.
- The operation parameters (Table 6-3) include building temperature set points, setbacks, schedules, etc. Key operational parameters should be short-term metered to verify that only the improvement in U-value and reduced infiltration are being applied to savings. Reduced equipment run time should also be verified.
- The model will ultimately predict energy savings. The energy model will be calibrated with past utility data and spot measurements. The recorded data will be used as inputs to the model.

Table 6-3. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Conduction			
Performance	Baseline	Insulation R-value with framing (entire structure)	Calculated using ASHRAE 90.1 standards
Performance	Post-Installation	Insulation R-value with framing (entire structure)	Calculated using ASHRAE 90.1 standards
Performance	Performance	None	None
Infiltration			
Performance	Baseline	Entire structure or areas with high infiltration rates	Calculated using ASHRAE crack method/ACH method
Performance	Post-Installation	Entire structure or areas with high infiltration rates	Calculated using ASHRAE crack method/ACH method
Performance	Performance	None	None

6.4.1.3 M&V Performance Assurance Activities

- Verify installation of improved building envelope material.
- Perform standard ASHRAE calculations to verify reduced heat transfer and infiltration.
- Perform short-term metering to verify building operation has remained consistent or that changes in operation have been taken into consideration.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.5 ECM: ENERGY MANAGEMENT CONTROL SYSTEM

6.5.1 M&V Option D

This measure involves installing controls that allow for optimized control of heating, ventilation, and air conditioning (HVAC) equipment and other energy consuming devices.

6.5.1.1 M&V Plan Description

Option D (Calibrated Simulation) will be used to quantify the energy consumption savings associated with the energy management control system (EMCS) controls. Option D is recommended due to the interactions between energy consuming equipment when controls are implemented.

Option D will be used to validate ECM performance during the performance period.

6.5.1.2 M&V Option Selection Rationale

- The EMCS provides an excellent source of data collection and thus will be used to implement this ECM's M&V.
- Option D is recommended for ongoing verification of the performance of this ECM. Under this strategy, ongoing performance measurements [i.e., air handling unit (AHU) run time, reset schedules, etc.] are not performed. Rather, a review of EMCS trend logs on an annual basis will be used to validate ECM performance.
- Performance parameters of identified HVAC equipment (Table 6-4) will be short-term data logged during the baseline and post-installation periods. The performance parameters will be collected from the EMCS trending data during the performance period. This will reduce M&V costs. Because of the large quantity of HVAC equipment, data logging and testing will be completed on a representative sample of the equipment and extrapolated for the remaining equipment.
- Operational parameters (temperature set points, setbacks, reset schedules, run times, etc.) will be determined during the short-term data logging conducted for a representative number of the existing equipment to verify the operating schedules (Table 6-4).
- Post-installation, operation of EMCS will be verified during the commissioning process to ensure functionality.

Table 6-4. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
HVAC Equipment Power (kW)			
Performance	Baseline	20% (focus on larger HVAC equipment with controls)	Short-term metering
Performance	Post-Installation	20% (focus on larger HVAC equipment with controls)	Short-term metering
Performance	Performance	Review trend logs	From EMCS

Table 6-4. M&V Plan Performance and Operational Parameters (continued)

Parameter	Period	Population	Measurement
HVAC Equipment Run Time (hours)			
Operation	Baseline	20% (focus on larger HVAC equipment with controls)	Short-term metering
Operation	Post-Installation	20% (focus on larger HVAC equipment with controls)	Short-term metering
Operation	Performance	Review trend logs	From EMCS
Temperature Set points, Setbacks (°F)			
Operation	Baseline	20% (focus on similar spaces with majority of building space)	Short-term metering
Operation	Post-Installation	20% (focus on similar spaces with majority of building space)	Short-term metering
Operation	Performance	Review trend logs	From EMCS
Temperature Reset Schedules (°F)			
Operation	Baseline	20% (focus on larger HVAC equipment with controls)	Short-term metering
Operation	Post-Installation	20% (focus on larger HVAC equipment with controls)	Short-term metering
Operation	Performance	Review trend logs	From EMCS

6.5.1.3 M&V Performance Assurance Activities

- Verify installation of control hardware.
- Verify that spaces are achieving desired heating and cooling set points.
- Perform a post-installation short-term metering and use the EMCS trending data during the performance period to demonstrate energy savings.
- Annual review of EMCS trend logs to validate ECM performance.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Verify that operators have received training in operating the new system.

6.6 ECM: PREMIUM EFFICIENCY MOTORS

6.6.1 M&V Option A

This measure involves replacing standard efficiency motors with National Electrical Manufacturers Association (NEMA) premium efficiency motors.

6.6.1.1 M&V Plan Description

Option A (Retrofit Isolation with Key Parameter Measurement) will be used to quantify the energy consumption savings associated with premium efficiency motors.

6.6.1.2 M&V Option Selection Rationale

- Installation of premium efficiency motors is a simple ECM with savings that are a function of improved efficiency, run hours, and motor kilowatts.
- Option A is recommended for verification of the performance this ECM. Savings will be based on kilowatt reduction by installing a more efficient motor.
- The performance parameters to be collected are motor kilowatts (Table 6-5) and run time through short-term metering, where applicable. This short-term measurement will be completed during the baseline development and commissioning. Performance period savings are based on information collected during commissioning. It is crucial that the kilowatt measurement be conducted during the same load conditions or normalized for motor load. It is also recommended to re-sheave the motors to prevent the operating speed from increasing.
- Operational parameters (power and run time; Table 6-5) will be determined during the short-term data logging conducted for a representative number of the existing motors during the baseline development and commissioning. The performance period savings will be based on commissioned findings.

Table 6-5. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Motor Power Information			
Performance	Baseline	Collect nameplate data on all motors; measure kilowatts	Spot metering
Performance	Post-Installation	Collect nameplate data on all motors; measure kilowatts	Spot metering
Performance	Performance	Based on commissioning	None
Motor Run Time (hours)			
Operation	Baseline	20% (focus on large motors >20 hp)	Short-term metering
Operation	Post-Installation	20% (focus on large motors >20 hp)	Stipulated
Operation	Performance	Based on commissioning	Stipulated

6.6.1.3 M&V Performance Assurance Activities

- Verify installation of NEMA premium efficiency motors.
- Use measured kilowatts to verify savings.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.7 ECM: VARIABLE AIR VOLUME CONVERSION

6.7.1 M&V Option D

This measure involves replacing constant volume air handlers with variable air volume (VAV) air handlers with VAV terminals. VAV conversion saves energy by reducing the volume of air being supplied to the space. This not only reduces fan power but also saves heating and cooling energy by reducing the amount of air to be conditioned.

6.7.1.1 M&V Plan Description

Option D (Calibrated Simulation) will be used to quantify the energy consumption savings associated with VAV measures. Option D is recommended due to the interactions between HVAC equipment and building loads.

6.7.1.2 M&V Option Selection Rationale

- VAV savings vary based on many parameters including existing equipment efficiency, cooling load, heating load, part-load HVAC performance, and run hours. Because of the multiple interactions between HVAC equipment and building load it is recommended to determine savings using an energy analysis model conforming to ASHRAE 90.1 Appendix G requirements, calibrated to utility data for the building, or short-term metered data (see Table 6-6).
- During the performance period, performance is assured through review of trend logs to ensure set points are being maintained and by inspection of the equipment to ensure proper operation.

Table 6-6. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Fan Power (kW; run time based on measurements)			
Performance	Baseline	20% (focus on larger AHUs)	Short-term metering
Performance	Post-Installation	Review trend logs	From EMCS
Performance	Performance	Review trend logs	From EMCS
Fan Flow (cubic feet per minute or based on speed)			
Performance	Baseline	20% (focus on larger AHUs)	Short-term metering
Performance	Post-Installation	Review trend logs	From EMCS
Performance	Performance	Review trend logs	From EMCS
Supply and Return Air Temperature (°F)			
Performance	Baseline	20% (focus on larger AHUs)	Short-term metering
Performance	Post-Installation	Review trend logs	From EMCS
Performance	Performance	Review trend logs	From EMCS

6.7.1.3 M&V Performance Assurance Activities

- Verify installation of variable speed drives (VSDs), VAV boxes, and controls.
- Verify that the VSD is not in bypass mode.
- Verify the operation of control sensors.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.8 ECM: VARIABLE SPEED PUMPING

6.8.1 M&V Option A

This measure involves the addition of variable speed drives (VSDs) to pumping systems. Savings are a result of improved part-load pumping efficiencies.

6.8.1.1 M&V Plan Description

Option A (Retrofit Isolation with Key Parameter Measurement) will be used to quantify the energy consumption savings associated with variable speed pumping. Option A is recommended due to the low number of parameters to be collected.

6.8.1.2 M&V Option Selection Rationale

- VSDs on pumps is a standard ECM with demonstrated savings. However, each system is slightly different and savings vary based on system design, existing controls, proposed controls, and system requirements. Savings will be determined from the reduced post-condition kilowatts from speed reduction and by applying the logged run hours.
- Option A is recommended for verification of the performance of this ECM.
- Performance parameters (Table 6-7) include pump power during the baseline development, commissioning, and performance period. It is recommended to perform short-term metering and rotate through a small percentage of the pumps each year during the performance period.
- Operational parameters (run time, flow, and pump discharge pressure) will be determined during the short-term data logging conducted for a representative number of the existing pumps to verify run time and flow and that a constant discharge pressure is being maintained during the baseline development and commissioning. It is recommended to record pump flow directly through flow sensors; however, this is not always a viable option. If flow is not measured, it is recommended to base flow off the pump curves. Pump power needs to be normalized with flow requirements using a regression analysis. The performance period savings will be based on commissioned findings. A constant discharge pressure demonstrates that the system requirements are being meet and that the VSD is operating as intended.

Table 6-7. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Pump Power (kW; run time based on measurement)			
Performance	Baseline	100% on pumps larger than 20 hp	Short-term metering
Performance	Post-Installation	100% on pumps larger than 20 hp	Short-term metering
Performance	Performance	20% rotating among pumps over 20 hp	Short-term metering

Table 6-7. M&V Plan Performance and Operational Parameters (continued)

Parameter	Period	Population	Measurement
Pump Flow (GPM)			
Operation	Baseline	100% on pumps larger than 20 hp	Short-term metering or based on pump curves
Operation	Post-Installation	100% on pumps larger than 20 hp	Short-term metering or based on pump curves
Operation	Performance	Based on commissioning	None
Pump Discharge Pressure (PSIG)			
Operation	Baseline	100% on pumps larger than 20 hp	Short-term metering
Operation	Post-Installation	100% on pumps larger than 20 hp	Short-term metering
Operation	Performance	Based on commissioning	None

6.8.1.3 M&V Performance Assurance Activities

- Verify installation of VSDs and controls.
- Perform a post-installation review of system operation with short-term metering on pump power, run time, and discharge pressure.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.9 ECM: STEAM TRAP REPLACEMENT

6.9.1 M&V Option A

This measure involves replacing steam traps. This will improve return water quantity and temperature, which will reduce boiler consumption and water treatment chemicals for makeup water.

6.9.1.1 M&V Plan Description

Option A (Retrofit Isolation with Key Parameter Measurement) will be used to quantify the energy consumption savings associated with steam trap replacement.

6.9.1.2 M&V Option Selection Rationale

- This measure is detailed with multiple measurements and calculations required to verify savings. It is recommended to perform a routine steam trap assessment to verify savings are being maintained.
- Option A is recommended for verification of the performance of this ECM.
- Performance parameters (Table 6-8) include a steam trap assessment of the entire facility. This will identify the failed traps. Once the failed traps have been identified, the steam pressure and orifice size will be required to calculate losses. This will be done during the

baseline development, commissioning, and performance period with 20% of the steam traps being assessed every year and rotated.

Table 6-8. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Steam Trap Assessment			
Performance	Baseline	Entire facility	Thermograph/ultrasonic
Performance	Post-Installation	Entire facility	Thermograph/ultrasonic
Performance	Performance	20% rotating	Thermograph/ultrasonic
Steam Pressure and Orifice Size			
Performance	Baseline	For all traps failed	Spot measurement
Performance	Post-Installation	For all traps failed	Spot measurement
Performance	Performance	Based on baseline	None
Steam Trap Operation			
Operation	Baseline	Entire facility	Hours based on boiler logs
Operation	Post-Installation	Based on baseline	None
Operation	Performance	Based on baseline	None

6.9.1.3 M&V Performance Assurance Activities

- Verify failed traps have been replaced with proper replacement.
- Verify savings through calculated losses by verifying trap orifice size and steam pressure.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.10 ECM: DISTRIBUTED HIGH EFFICIENCY BOILERS

6.10.1 M&V Option A

This measure involves switching from a central steam or hot water plant to distributed high efficiency boilers. Savings are the result of reduced distribution losses and improved boiler efficiency.

6.10.1.1 M&V Plan Description

Option A (Retrofit Isolation With Key Parameter Measurement) will be used to quantify the energy consumption savings associated with distributed high efficiency boilers. Boiler loads (annual output in MMBTU) shall be established using boiler logs from the baseline period. Gas savings shall be calculated based on the efficiency of the replacement boilers and the baseline equipment.

6.10.1.2 M&V Option Selection Rationale

- Option A is recommended for verification of the performance of this ECM.
- Performance parameters (Table 6-9) include the performance of a combustion efficiency test on all boilers during baseline development, commissioning, and the performance period. Additional water savings may be applied if the distribution losses are proven to be significant. If viable, the water savings associated with this measure should be identified and tracked during the baseline development and commissioning period.

Table 6-9. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Boiler Combustion Efficiency			
Performance	Baseline	All boilers	Spot check
Performance	Post-Installation	All boilers	Spot check
Performance	Performance	All boilers	Spot check

6.10.1.3 M&V Performance Assurance Activities

- Verify installation of distributed high efficiency boilers.
- Verify boilers are operating as intended via combustion efficiency tests.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.11 ECM: STEAM/HOT WATER/CHILLED WATER EQUIPMENT REPLACEMENT

6.11.1 M&V Option D

This measure involves replacing existing central plant equipment with more efficient equipment and controls.

6.11.1.1 M&V Plan Description

Option D will be used to quantify the energy consumption savings associated with improved plant efficiency. Option D will be used during the performance period of the contract.

6.11.1.2 M&V Option Selection Rationale

- The overall savings associated with this measure can be easily quantified by measuring the efficiency of the installed equipment and run time. The efficiency and run time will be used to determine savings within the energy model that meets the requirements of ASHRAE 90.1 Appendix G.
- Performance parameters (Table 6-10) include the spot measurement of plant efficiency. For chillers this is kilowatts per ton and for boilers this is steam efficiency. Plant efficiency should be recorded during the baseline development, commissioning, and performance

period. The measured efficiency will need to be normalized for load and weather and used within the model to estimate savings.

- The model will ultimately predict energy savings. It is recommended that the energy model be calibrated with past utility data and spot measurements. The recorded data will be used as inputs into the model.

Table 6-10. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Overall Plant Efficiency (At Varying Loads to Verify)			
Performance	Baseline	All equipment	Spot check
Performance	Post-Installation	All equipment	Spot check
Performance	Performance	Trending of all equipment	EMCS
Metered Electrical/Gas Consumption			
Operation	Baseline	All equipment	Submetering
Operation	Post-Installation	All equipment	Submetering
Operation	Performance	Trending of all equipment	EMCS

6.11.1.3 M&V Performance Assurance Activities

- Verify installation of new plant equipment and efficiency.
- Consider having ESCO obtain manufacturer's bench test results for equipment.
- Perform efficiency spot checks on equipment to ensure efficiency has improved.
- Perform long-term logging on plant run time to verify reduced operating hours.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.12 ECM: RENEWABLE GENERATION

6.12.1 M&V Option B

This energy conservation measure involves installing a renewable energy source to produce site energy. The M&V plan includes renewable energy measures that produce electric power such as biodiesel, biomass, photovoltaics, and wind power. These are independent measures that offset current facility energy consumption.

6.12.1.1 M&V Plan Description

Option B will be used to quantify the energy consumption savings associated with renewable energy.

6.12.1.2 M&V Option Selection Rationale

- The overall savings associated with this measure can be easily quantified by measuring the generated (electrical) power from the renewable source. Typically the renewable energy is submetered for net metering purposes.
- Option B is recommended for ongoing verification of the performance of this ECM.
- Performance parameters (Table 6-11) include the measurement of generated power from the renewable source. This is typically submetered and should be verified by utility data. This will be accomplished during the baseline and commissioning and throughout the performance period. A utility data analysis will be completed each year to verify generated savings.
- By collecting the proper utility data the run time will also be verified through metered data. This will be accomplished during baseline development, commissioning, and the performance period.

Table 6-11. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Generated Kilowatts and Kilowatt-Hours (run hours based on measurement)			
Performance/Operation	Baseline	Entire renewable generation	Metered data
Performance/Operation	Post-Installation	Entire renewable generation	Metered data
Performance/Operation	Performance	Entire renewable generation	Metered data

6.12.1.3 M&V Performance Assurance Activities

- Verify installation of renewable energy system.
- Submeter the renewable energy source to verify energy production and savings.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.13 ECM: RENEWABLE OFFSET

6.13.1 M&V Option D

This measure involves installing a renewable energy source to offset current energy consumption. This includes solar thermal, ground-source heat pumps, and other renewable energies that offset equipment run time and improve efficiency.

6.13.1.1 M&V Plan Description

Option D will be used to quantify the energy consumption savings associated with renewable energy. Option D will be used during the performance period of the contract.

6.13.1.2 M&V Option Selection Rationale

- The overall savings associated with this measure vary based on load, weather conditions, existing equipment type, efficiencies, and controls. It is recommended to use an energy model that meets the requirements of ASHRAE 90.1 Appendix G to analyze the savings from installing renewable energies that improve equipment efficiency.
- Option D is recommended for ongoing verification of the performance of this ECM.
- Performance parameters (Table 6-12) include the measurement of equipment efficiency or output. Measurements will be normalized with load and weather. Equipment efficiency or output will be determined during the baseline development, commissioning, and performance period. The measured data will be used as inputs for the energy model. The energy model needs to be tuned to past utility data to verify it is calibrated.
- The operating parameters (Table 6-12) include run time, which will be collected during the baseline development, commissioning, and performance period. This measurement should be compared to the modeled output files to verify that the equipment run time has been reduced.

Table 6-12. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Plant Efficiency			
Performance	Baseline	Renewable source	Short-term metering
Performance	Post-Installation	Renewable source	Short-term metering
Performance	Performance	Renewable source	Short-term metering
Equipment Run Time (hours)			
Operation	Baseline	Renewable source	Short-term metering
Operation	Post-Installation	Renewable source	Short-term metering
Operation	Performance	Renewable source	Short-term metering

6.13.1.3 M&V Performance Assurance Activities

- Verify installation of the renewable energy system.
- Submeter the renewable energy source to verify energy production and savings if practical.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.14 ECM: HEAT RECOVERY SYSTEMS

6.14.1 M&V Option D

This measure involves the installation of heat recovery units (HRUs) on existing AHUs to reduce HVAC heating and cooling energy. There are a variety of HRU options; however the M&V approach is similar for all types.

6.14.1.1 M&V Plan Description

Option D will be used to quantify the energy consumption savings associated with HRUs. Option D is recommended due to the interactions between HVAC equipment and building loads.

6.14.1.2 M&V Option Selection Rationale

- Heat recovery effectiveness varies based on air flow and temperature differences. Air temperature and airflow varies throughout the year depending on the building conditioning demand and outside air conditions. Due to the multiple interactions between HVAC equipment and building load it is recommended to develop an energy analysis model using software that conforms to ASHRAE 90.1 Appendix G requirements.
- Performance parameters (Table 6-13) include fan flow, supply enthalpy difference, and exhaust enthalpy difference across the heat exchanger. These values will determine HRU effectiveness, which will be a key parameter used in the energy model, and will be collected via short term data logging. The collected data will be used to verify modeled savings. This is best accomplished by comparing daily output files from the model to collected measured data. The performance parameter will be collected yearly and rotated through all HRUs to verify proper operation. Direct cubic feet per minute measurements are difficult to perform, but the flow could be based on the fan curves and the measured speed of the drive.
- Operational parameters (run times) will be verified by measuring AHU run times. This short-term data logging will be conducted for a representative number of the existing AHUs to verify run times during the baseline development and commissioning. The data will be used to verify modeled operation. The performance period savings will be based on a smaller percentage of HRUs and rotated through all HRUs through the life of the contract.

Table 6-13. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Supply Air Enthalpy Pre- and Post-Heat Recovery			
Performance	Baseline	50% of HRUs	Short-term metering
Performance	Post-Installation	50% of HRUs	Short-term metering
Performance	Performance	20% of HRUs (rotating)	Short-term metering
Exhaust Air Enthalpy Pre- and Post-Heat Recovery			
Performance	Baseline	50% of HRUs	Short-term metering
Performance	Post-Installation	50% of HRUs	Short-term metering
Performance	Performance	20% of HRUs (rotating)	Short-term metering
Supply and Exhaust Air Flow			
Performance	Baseline	50% of HRUs	Short-term metering
Performance	Post-Installation	50% of HRUs	Short-term metering
Performance	Performance	20% of HRUs (rotating)	Short-term metering

Table 6-13. M&V Plan Performance and Operational Parameters (continued)

Parameter	Period	Population	Measurement
Equipment Run Time (hours)			
Operation	Baseline	50% of HRUs	Long-term metering
Operation	Post-Installation	Baseline	None
Operation	Performance	Baseline	None

6.14.1.3 M&V Performance Assurance Activities

- Verify installation of HRU, controls, and programming.
- Verify heat exchanger effectiveness that is used to model heat exchanger performance within the energy model.
- Verify operation of the HRU through logged data.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.15 ECM: THERMAL ENERGY STORAGE

6.15.1 M&V Option B

This measure involves installing thermal energy storage (TES) to reduce peak demand charge. Chilled water is produced and stored during periods when demand charges are low (typically at night). Stored chilled water is then supplied to meet cooling loads when demand charges are higher.

6.15.1.1 M&V Plan Description

Option B will be used to quantify the demand cost reductions associated with TES.

6.15.1.2 M&V Option Selection Rationale

- The overall cost savings associated with this measure can be easily quantified by measuring the flow rate, temperature difference, and source efficiency of the chiller to determine the cooling load it replaces, and calculating the power draw of the baseline equipment to determine the demand reduction.
- Option B is recommended for ongoing verification of the performance of this ECM.

Table 6-14. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Reduced Kilowatts			
Chiller efficiency	Baseline	TES system	Short-term measurement
Flow rate, temperature difference, and chiller efficiency	Post-Installation	TES system	Short-term measurements
Flow rate, temperature difference, and chiller efficiency	Performance	TES system	Short-term measurements

6.15.1.3 M&V Performance Assurance Activities

- Verify installation of TES.
- Savings are based on reduction in power demand from the baseline.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.16 ECM: AIR COMPRESSOR AND VACUUM PUMP IMPROVEMENTS

6.16.1 M&V Option B

This measure involves improving the operation and efficiency of the air compressors and vacuum pumps at the facility. Only select measures will be implemented based on performance savings.

6.16.1.1 M&V Plan Description

Option B will be used to quantify the energy consumption savings associated with improved compressor/vacuum controls, system upgrades, and efficiency. Option B will be used during the performance period of the contract.

6.16.1.2 M&V Option Selection Rationale

- The overall savings associated with this measure can be quantified by measuring the efficiency of the retrofit compressors/vacuums with improved controls, system upgrades, and higher efficiency ratings.
- Option B is recommended for ongoing verification of the performance of this ECM.
- Performance parameters (Table 6-15) include short-term data logging of the compressor kilowatts to verify efficiency improvements. It is also recommended to spot check the vacuum level and compressor storage pressure to verify that the system is maintaining required set points as desired. These measurements will be taken during the baseline development, commissioning, and performance period. The M&V plan will need to verify

that the vacuum pump or compressor is serving the same load; if the load varies it will need to be normalized within the analysis.

- The compressor/vacuum pump run time will also be collected during baseline development, commissioning, and throughout the life of the contract. This will demonstrate the reduced run time with system upgrades and improved controls.

Table 6-15. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Compressor/Vacuum Pump Kilowatts			
Performance	Baseline	All compressors/vacuum pumps above 20 hp	Short-term metering
Performance	Post-Installation	All compressors/vacuum pumps above 20 hp	Short-term metering
Performance	Performance	All compressors/vacuum pumps above 20 hp	Short-term metering
Compressor/Vacuum Pump (Maintained Vacuum or Pressure)			
Performance	Baseline	All compressors/vacuum pumps above 20 hp	Spot check
Performance	Post-Installation	All compressors/vacuum pumps above 20 hp	Spot check
Performance	Performance	All compressors/vacuum pumps above 20 hp	Spot check
Run Time			
Operation	Baseline	All compressors/vacuum pumps above 20 hp	Short-term metering
Operation	Post-Installation	All compressors/vacuum pumps above 20 hp	Short-term metering
Operation	Performance	All compressors/vacuum pumps above 20 hp	Short-term metering

6.16.1.3 M&V Performance Assurance Activities

- Verify installation of upgraded compressor/vacuum, improved controls, and improved system upgrades.
- Perform measurements on kilowatts for improved efficiency.
- Perform measurements on vacuum/pressure levels to verify maintained set points.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.17 ECM: REPLACE SELF-CONTAINED AIR CONDITIONING WITH CHILLED WATER

6.17.1 M&V Option D

This measure involves the installation of either a centralized air system or fan coils to provide cooling to an existing area that is currently cooled with self-contained air conditioning (AC). Self-contained AC is not an efficient approach due to poor operating efficiencies and lack of system control or monitoring capabilities.

6.17.1.1 M&V Plan Description

Option D will be used to quantify the energy consumption savings associated with replacement of self-contained AC units with chilled water or a central air system. Option D is recommended due to the interactions between HVAC equipment and building loads.

6.17.1.2 M&V Option Selection Rationale

- Savings vary based on many parameters including existing equipment efficiency, cooling load, heating load, part-load HVAC performance, and run hours. Due to the multiple interactions between HVAC equipment and building load it is recommended to develop an energy analysis model using software that conforms to ASHRAE 90.1 Appendix G requirements.
- Performance parameters (Table 6-16) include unit power. This should be easy to obtain for the baseline development by measuring unit kilowatts; however, the commissioning may require flow and temperature difference to determine newly installed energy consumption. It is also recommended to monitor a small portion of installed HVAC equipment to verify proper operation and rotate these measurements among equipment. These will be collected via short-term data logging. The collected data will be used to verify modeled savings. This is best accomplished by comparing daily output files from the model to collected measured data. The performance parameter will be collected yearly and rotated through all air handlers to verify proper operation of the newly installed central air system or piped fan coil system. Direct flow measurements are difficult to quantify, but the flow could be based on the fan and pump curves and the measured speed of the drive.
- Operational parameters (run times) will be verified by measuring unit power. This short-term data logging will be conducted for a representative number of the existing AHUs to verify run times during the baseline development and commissioning. These data will be used to verify AHU-modeled operation. The performance period savings will be based on commissioned findings.

Table 6-16. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Unit Power			
Performance	Baseline	All AC units over 3 tons (kW)	Short-term metering
Performance	Post-Installation	All AC units over 3 tons (flow times temperature delta)	Short-term metering
Performance	Performance	10% rotating among units	Short-term metering
Run Time			
Performance	Baseline	All AC units over 3 tons	Short-term metering
Performance	Post-Installation	All AC units over 3 tons	Short-term metering
Performance	Performance	Based on commissioning	Short-term metering

6.17.1.3 M&V Performance Assurance Activities

- Verify installation of new equipment and controls.
- Verify operational schedules.

- Verify newly installed power requirements through either power measurements or room unit flow and temperature difference for rooms that have been upgraded above self-contained AC.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.18 ECM: WATER CONSERVATION MEASURES

6.18.1 M&V Option A

This measure involves the retrofit of water consuming devices with controls and related equipment. This measure investigates the savings associated with installing waterless urinals, low-flow water closets, optical sensors on sinks, low-flow showerheads, and improved irrigation watering techniques.

6.18.1.1 M&V Plan Description

Option A will be used to quantify water savings. Measurements of water flow will be taken pre- and post-installation.

6.18.1.2 M&V Option Selection Rationale

Water use per fixture can be measured and total water use estimated using industry standards based on building occupancy. If the number of fixtures is large, extensive ongoing M&V may not be cost-effective. Performance and operational parameters can be mutually agreed upon and used to estimate annual savings, reducing the cost to verify the ECM's performance.

- Performance and operational parameters for this ECM (Table 6-17) will be determined using field survey information, customer provided historical water consumption records, and industry standards.
- Based on the information collected, both the performance and operational parameters will be stipulated for this ECM. Baseline adjustment will not be required as operational parameters may be stipulated.

Table 6-17. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Water Usage per Measure			
Performance	Baseline	10% precision with 90% confidence or 20% precision with 80% confidence	Spot or short-term metering
Performance	Post-Installation	10% precision with 90% confidence or 20% precision with 80% confidence	Spot or short-term metering
Performance	Performance	Verified at commissioning	None

6.18.1.3 M&V Performance Assurance Activities

- High level water balance recommended to ensure baseline and savings calculation are reasonable.

- Perform a one-time post-installation sample set of measurements of fixture water flow (gallons per minute or gallons per flush) if practical.
- Annually perform a visual inspection of a sample set of the installed water use fixtures in selected facilities to ensure the integrity of the devices in affected buildings and that the ECM still has the potential to perform.
- Obtain customer approval of all stipulated performance and operational parameters shown.

6.19 ECM: COOLING TOWER WATER METER

6.19.1 M&V Option B

This measure involves installing a separate meter on the supply makeup water for central plant cooling towers.

6.19.1.1 M&V Plan Description

Option B will be used to quantify the cost reductions associated with an individual water meter.

6.19.1.2 M&V Option Selection Rationale

- The overall cost savings associated with this measure can be easily quantified by performing a utility bill analysis and verifying the reduced sewer charge due to metering the makeup water to the cooling towers. Makeup water to cooling towers is lost due to the evaporative effects of the cooling tower. This measure is typically only for facilities with a large central plant with centralized cooling towers.
- Option B is recommended for ongoing verification of the performance of this ECM.
- Performance parameters (Table 6-18) include the verification of reduced sewer charges based on the cooling tower meter. This should be verified through a utility bill analysis of reduced sewer charges. This will be accomplished during the baseline and commissioning and throughout the performance period.
- By collecting the proper utility data, the run time will also be verified through metered data. This will be accomplished during baseline development, commissioning, and the performance period.

Table 6-18. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Reduced Sewer Charge			
Performance/Operation	Baseline	Cooling tower meter	Metered data
Performance/Operation	Post-Installation	Cooling tower meter	Metered data
Performance/Operation	Performance	Cooling tower meter	Metered data

6.19.1.3 M&V Performance Assurance Activities

- Verify installation of cooling tower makeup water meter.

- Verify savings from actual utility data.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.20 ECM: RETROCOMMISSIONING/RECOMMISSIONING

6.20.1 M&V Option D

This ECM involves a recommissioning or retrocommissioning of the site. Recommissioning applies to equipment that was previously commissioned, while retrocommissioning applies to equipment that was never commissioned. Retrocommissioning and recommissioning typically include the savings associated with repair or extension of and upgrades to the existing operating controls at the facility.

6.20.1.1 M&V Plan Description

Option D will be used to quantify the energy consumption savings associated with the retrocommissioning/recommissioning. Option D is recommended due to the interactions between HVAC equipment and building loads.

6.20.1.2 M&V Option Selection Rationale

- Savings vary based on many parameters including operation, efficiencies, working controls, malfunction controls, set points, etc. Because of the multiple interactions between HVAC equipment and building load it is recommended to develop an energy analysis model using software that conforms to ASHRAE 90.1 Appendix G requirements.
- Performance parameters (Table 6-19) include space set points, airflow, and supply temperatures. Retrocommissioning/recommissioning improves the performance of the existing equipment. The performance parameters selected will be those that generate the most savings. It is recommended that performance parameters be verified through an EMCS during the performance period.
- The only operational parameter is equipment run time. It is recommended to perform short-term data logging during the baseline development and use the EMCS system during commissioning and the performance period. It is recommended to meter key equipment that will have the largest effect on savings (Table 6-19). It is recommended to continue measurements throughout the life of the contract to verify savings are being maintained.

Table 6-19. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Space Set points			
Performance	Baseline	All spaces	Short-term metering
Performance	Post-Installation	All spaces	Trending of EMCS logs
Performance	Performance	All spaces	Trending of EMCS logs
AHU Airflows and Supply Temperatures			
Performance	Baseline	All AHUs	Short-term metering

Table 6-19. M&V Plan Performance and Operational Parameters (continued)

Parameter	Period	Population	Measurement
Performance	Post-Installation	All AHUs	Trending of EMCS logs
Performance	Performance	All AHUs	Trending of EMCS logs
Equipment Run Time			
Operation	Baseline	Key equipment	Short-term metering
Operation	Post-Installation	Key equipment	Trending of EMCS logs
Operation	Performance	Key equipment	Trending of EMCS logs

6.20.1.3 M&V Performance Assurance Activities

- Verify installation of new equipment and controls.
- Verify savings through measured power measurements.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.

Note: This is not intended to be an exhaustive list of terms. If there is any discrepancy between the definitions in this document and those in a federal performance contract or task order, the definitions in the contract or task order prevail.

Definition of Terms

TERM	DEFINITION
Adjustments, Nonroutine & Routine	Changes made to the baseline and/or the performance period energy use to account for changes. Routine adjustments are used to account for expected variations in independent variables; Nonroutine adjustments are used to compensate for unexpected changes unrelated to the energy conservation measures (ECMs).
Annual Report	A report issued annually, typically on the anniversary of project acceptance, which documents the execution and results of the M&V activities prescribed in the M&V plan. This documentation verifies the continued operation of the ECMs, provides the associated energy savings estimates, demonstrates proper maintenance, and provides M&V results. In an ESPC, the energy savings documented in the report serves as the basis for the ESCO's invoice after the regular interval report has been reviewed and approved by the customer.
Avoided Energy Use	The reductions in energy use that occurred during the performance period relative to what would have been used during the baseline period, using actual operating conditions experienced during that period. This may require baseline energy use to be adjusted to actual conditions. This approach is different than calculating normalized savings.
Baseline Conditions	Physical conditions that existed before implementation of the energy savings measures (such as equipment inventory and conditions, occupancy, nameplate data, energy consumption rate, and control strategies), which are determined through surveys, inspections, spot measurements, and short-term metering activities. Baseline conditions are established for the purpose of estimating savings and are also used to account for any changes that may occur during the post-installation period, which may require adjustments to baseline energy use.
Baseline Energy or Demand	The calculated or measured energy use or demand by a piece of equipment or a site before implementation of the project.
Commissioning	The process of documenting and verifying through adjusting/remedying the performance of building facility systems so that they operate in conformity with the design intent. An independent party may complete system/equipment commissioning. The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Guideline 0-2013, *The Commissioning Process*, can be the basis for commissioning activities.
Energy Conservation Measure or Water Conservation Measure (ECM)	A measure that results in the reduction of energy or water use. In a federal ESPC, a measure must satisfy four statutory criteria to qualify as an "energy conservation measure." It must (1) be applied to a federal building; (2) improve energy efficiency; (3) be life cycle cost- effective; and (4) involve energy conservation, cogeneration facilities, renewable energy sources, improvements in operation and maintenance efficiencies, or retrofit activities. *See* 42 U.S.C. § 8259(4); 10 C.F.R. §436.31. A measure must satisfy three statutory criteria to qualify as a "water conservation measure." It must (1) improve the efficiency of water use; (2) be life cycle cost-effective; and (3) involve water conservation, water recycling or reuse, more efficient treatment of wastewater or storm water, improvements in operation or maintenance efficiencies, retrofit activities, or other related activities, not at a federal hydroelectric facility. *See* 42 U.S.C. § 8287c(4)(B).
Energy Services Company (ESCO)	An organization that designs, finances, procures, installs, and possibly maintains one or more ECMs or systems at a facility or facilities, typically under a performance contract or task order.

TERM	DEFINITION
Expected Savings	Expected savings are those reported in the post-installation report. They are based on as-built conditions and post-installation verification activities, and are the savings expected for year 1 of the project.
Independent Variable	A parameter that is expected to change regularly and have a measurable effect on the energy use of a building or system.
Insolation	A measure of solar radiation energy received on a given surface area in a given time.
Interactive Effects	Energy consumption changes to one system resulting from changes made to another building system.
Investment Grade Audit (IGA)	A comprehensive assessment of a facility's energy and water use characteristics, identifying and analyzing energy conservation measures. Also may be referred to as a feasibility study.
Measurement and Verification (M&V) Approach	An evaluation procedure for determining energy and cost savings. M&V techniques discussed in this document include engineering calculations, metering, utility billing analysis, and computer simulation.
M&V Option	One of four generic M&V approaches (A, B, C, and D) defined for ESPC projects. These options are defined in the IPMVP and in Section 4 of this document.
M&V Plan	The M&V plan is a document that defines project-specific M&V methods and techniques that will be used to determine savings resulting from a specific energy conservation project.
Measurements, Continuous	Measurements repeated at regular intervals over the baseline period or post-installation period.
Measurements, Long-Term	Measurements taken over a period of several years.
Measurements, Short-Term	Measurements taken for several hours, weeks, or months.
Measurements, Spot	Measurements taken one time; snap-shot measurements.
Normalized Savings	The reductions in energy use that occurred during the performance period relative to what would have been used during the baseline period, but adjusted to a normal set of conditions (such as typical weather conditions).
Operational Verification	Confirmation, through measurement and observation of performance, that installed equipment has the potential to deliver the guaranteed savings.
Performance Period	In an ESPC, the time period spanning from acceptance of ECMs to the end of the contract term or a specific time frame, such as 1 year, within that period.
Performance Period Energy Use or Demand	The calculated energy use (or demand) by a piece of equipment or a site after implementation of the project.
Post-Installation Conditions	The physical and operational conditions present during the time period following the installation of an energy conservation project.
Post-Installation Report	The report that provides results of post-installation M&V activities, documents any changes in the project scope that may have occurred during project implementation, and provides energy savings estimates for the first year of performance.
Preliminary Assessment	High-level assessment of whether or not a viable project exists at a site.
Project	The implementation of energy efficiency services at a federal facility or group of facilities.
Project-Specific M&V Plan	Plan providing details on how a specific project's savings will be verified based on the general M&V options described in this document.
Proposed Savings	Proposed savings are those estimated in the contract before project implementation and determined from metering and/or calculations performed in accordance with the provisions of the approved M&V plan.

TERM	DEFINITION
Regression Analysis	A technique used to develop a mathematical model from a set of data that describes the correlation of measured variables.
Sampling	A process of selecting random pieces of similar equipment for monitoring in order to characterize some feature of an entire population of equipment. This strategy is used when it is unrealistic to measure all affected equipment.
Usage Group	A collection of equipment (e.g., motors or rooms with light fixtures) with similar characteristics (e.g., operating schedule).
Verified Savings	For a federal ESPC project, verified savings are those reported in the annual report for the project. They are based on verification activities conducted during the performance period and are the savings calculated for that specific year of the project.

APPENDIX B. INCORPORATING M&V IN FEDERAL ESPCs—KEY SUBMITTALS

This section provides an overview of measurement and verification (M&V) submittals required in each phase of federal energy savings performance contract (ESPC) projects. The key submittals related to M&V in a federal ESPC project are outlined in Table B-1 and discussed below. In this table, the name of the federal ESPC submittal or item is shown in italics. Some of the terminology used specifically in federal ESPC projects is defined in Table B-2.

Table B-1. Federal ESPC Submittals Related to Measurement and Verification (M&V)[a]

Required M&V Item	Locations	Timing for Development
M&V Approach	*Preliminary Assessment*	Initial project scoping
Risk and Responsibility Matrix	*Preliminary Assessment* *Proposal*	Initial project scoping; before *Notice of Intent to Award* During *Investment Grade Audit (IGA)*
M&V Plan and Savings Calculation Methods	*Proposal*	After *Notice of Intent to Award* and during *IGA*
Commissioning Approach	*Proposal*	During *IGA*
Commissioning Plan	Separate submittal	After approval of design and construction package
Commissioning Report	Separate submittal	Before project acceptance
Post-Installation Report	Separate submittal	Before project acceptance
Annual Reports	Separate submittal	60 days after anniversary date of project acceptance, but depends on contract.

[a]Detailed information on the US Department of Energy ESPC process is available at http://energy.gov/eere/femp/articles/energy-savings-performance-contracts-0.

Table B-2. Energy Savings Performance Contract Project Terminology

Project Phase	Measurement and Verification (M&V) Submittal	Term Used
Project Development	M&V plan (final proposal)	Proposed savings
Project Acceptance	Post-installation report	Expected savings
Performance Period	Annual reports	Verified savings

B.1 M&V APPROACH

The first M&V-related item received on a federal ESPC project is the ECM performance measurement section of the preliminary assessment. This section provides a general description of the M&V plan proposed for the project. Although very little detail is included in this section, it is important that the agency and the ESCO agree on the general M&V approaches to be used before starting the investment grade audit (IGA). The M&V methods chosen can have a dramatic effect on how the baseline is defined, determining what activities are conducted during the IGA.

B.2 ESPC RISK AND RESPONSIBILITY MATRIX

A project-specific risk, responsibility, and performance matrix is required for federal ESPC projects. It is first presented in the preliminary assessment and is finalized in the final proposal.

The responsibility matrix details risks and responsibilities that should be considered when developing performance contracts, especially the verification requirements of these contracts. This responsibility matrix was developed to help identify the important project risks, assess their potential effects, and clarify the party responsible for managing the risk.

The final agreed-upon responsibility matrix will greatly influence the M&V approaches used in the project, which must reflect the allocation of responsibilities.

B.3 MEASUREMENT AND VERIFICATION PLAN

The project-specific M&V plan includes project-wide items and details for each ECM, including the following.

- Details of baseline conditions and data collected
- Documentation of all assumptions and sources of data
- What will be verified and when
- Who will conduct the M&V activities
- Agency witnessing requirements
- Schedule for all M&V activities
- Discussion on risk and savings uncertainty
- Details of engineering analysis performed
- Information on how energy and cost savings will be calculated
- Energy rate structures and escalation rates
- Details of any O&M cost savings claimed
- Definition of O&M reporting responsibilities
- Agreement on how and why the baseline (and therefore savings) may be adjusted

An outline for the M&V Plan is provided in Appendix C.

B.4 COMMISSIONING APPROACH, PLAN, AND REPORT

The commissioning approach for each ECM is included in the ECM performance measurement section of the final proposal. The commissioning approach outlines the expected commissioning activities and identifies roles and responsibilities of the ESCO and the federal agency.

The project-specific commissioning plan is developed after the engineering design is finalized and the design and construction package has been approved by the agency. The commissioning plan finalizes the commissioning approach outlined in the final proposal and addresses each ECM with specific steps that will be taken during the commissioning process.

Once commissioning activities have been completed and documented per the approved commissioning plan, the commissioning report is submitted. This report details the inspections and performance tests implemented, along with the results of these inspections and tests, to ensure that the systems were installed and performing properly. It also verifies systems and equipment are operating as intended and according to design intent.

For commissioning guidance for ESPCs, refer to FEMP's guidance, available at http://energy.gov/sites/prod/files/2013/10/f3/comm_guide_espc.pdf.

B.5 POST-INSTALLATION REPORT

After the commissioning activities have been completed, the post-installation verification activities defined in the M&V plan are conducted. The results of the post-installation verification activities are presented in the post-installation report, which is delivered by the ESCO before project acceptance. This report also documents any changes in the project scope and energy savings that may have occurred since the final proposal was submitted and accepted and reports the expected performance period year 1 energy and cost savings.

An outline for the post-installation report is provided in Appendix D.

B.6 ANNUAL INSPECTIONS AND REPORTS

Each year during the performance period, typically just after the anniversary of the project's acceptance, the contractor submits an annual report. The report documents the execution and results of the activities prescribed in the M&V plan (measurements, savings calculations) and reports the verified year 1 energy and cost savings. The report also describes operations and maintenance activities conducted during that performance period and identifies any items that may require additional follow-up.

For federal ESPC projects, M&V needs to show only that the overall cost savings guarantee has been met and not that the predicted savings for each ECM have been achieved.

The verified savings values presented in the annual report determine whether the annual savings guarantee has been met and whether any adjustment of payments is required. As stipulated in the contract or task order, the federal agency may use the annual report to reconcile payments made to the ESCO for previous billing periods if previous payments were based on expected savings that then need to be adjusted to reflect verified savings. The estimates in the report may also be used as the basis for subsequent payments.

An outline for the annual M&V report is provided in Appendix E.

B.7 CRITERIA FOR ENERGY CONSERVATION MEASURES

It is important to note that in a federal ESPC, a measure must satisfy four statutory criteria to qualify as an “energy conservation measure.” It must (1) be applied to a federal building; (2) improve energy efficiency; (3) be life cycle cost-effective; and (4) involve energy conservation, cogeneration facilities, renewable energy sources, improvements in operation and maintenance efficiencies, or retrofit activities. *See* 42 U.S.C. § 8259(4); 10 C.F.R. § 436.31. In addition, a measure must satisfy three statutory criteria to qualify as a “water conservation measure” in an ESPC. It must (1) improve the efficiency of water use; (2) be life cycle cost-effective; and (3) involve water conservation, water recycling or reuse, more efficient treatment of wastewater or storm water, improvements in operation or maintenance efficiencies, retrofit activities, or other related activities, not at a federal hydroelectric facility. *See* 42 U.S.C. § 8287c(4)(B).

A measure’s life cycle cost-effectiveness may be determined in accordance with Part 436, Subpart A, of Title 10 of the Code of Federal Regulations either using an approach that views individual ECMs in isolation or in the context of all contemplated ECMs within a “federal building” under the same project. Evaluating life cycle cost-effectiveness using a federal building-wide approach thus may account for the relationship of multiple ECMs under the same project that are located either within a single building, structure, or facility or among a collection of buildings, structures, or facilities (including geographically dispersed locations). *See* 42 U.S.C. §8259(6).

Measurement and Verification (M&V) Plan and Savings Calculation Methods Outline

[Note: All content called for in this outline is required (if applicable) except items noted as optional.]

1. Executive Summary/M&V Overview and Proposed Savings Calculations

1.1 Proposed Annual Savings Overview

Table C-1. Proposed Annual Savings Overview

[Include all applicable fuels/commodities for project, e.g., electric energy, electric demand, natural gas, fuel oil, coal, water, etc.]

ECM	Total energy savings (MBtu/ year)	Electric energy savings (kWh/ year)	Electric demand savings (kW/ year)*	Natural gas savings (MBtu/ year)	Water savings (gallons/ year)	Other energy savings (MBtu/ year)	Total energy & water cost savings, Year 1 ($/year)	Other energy-related O&M cost savings, Year 1 ($/year)	Total cost savings, Year 1 ($/year)
Total savings									
First Year Guaranteed Cost Savings: $									

Notes

*Annual electric demand savings (kW/year) is the sum of the monthly demand savings. MBtu=10^6 Btu.

If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to delivery order schedules (e.g., 0.003413 MBtu/kWh).

1.1.1 Site Use and Savings Overview (Optional)

- Fill in Table C-1A or provide equivalent information.

Table C-1A. Site Use and Savings Overview (Optional)

	Total energy (MBtu/year)	Electric energy (kWh/year)	Electric demand (kW/year)*	Natural gas (MBtu/year)	Water (gal/year)	Other energy (MBtu/year)
Total proposed project savings						
Usage for entire site**						
% Total site usage saved						
Project square footage (KSF)						
Total site square footage (KSF)						
% Total site area affected						

Notes

MBtu=10^6 Btu

*Annual electric demand savings (kW/year) is the sum of the monthly demand savings.

**Define usage period. KSF = 10^3 square feet.

If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to delivery order schedules (e.g., 0.003413 MBtu/kWh).

1.2 M&V Plan Summary

Table C-2. M&V Plan Summary

ECM	ECM Description	M&V Option Used[a]	Summary of M&V Plan

[a] M&V options include A, B, C, and D.

2. Whole Project Data/Global Assumptions

2.1 Risk & Responsibility

- Summarize approach to options
- Baseline development
- Post-installation verification activities
- Performance period

2.1.1 Summarize allocation of responsibility for key items related to M&V.

- Reference location of Risk & Responsibility Matrix[24] (if required).

[24] The Risk/Responsibility Matrix is Attachment 5 of the DOE ESPC IDIQ contract.

2.2 Energy, Water, and Operations & Maintenance (O&M) Rate Data

2.2.1 Detail baseline energy and water rates.

2.2.2 Provide performance period rate adjustment factors for energy, water, and O&M cost savings, if used.

2.3 Schedule & Reporting for Verification Activities

2.3.1 Define requirements for witnessing of measurements during

- Baseline development
- Post-installation verification activities
- Performance period

2.3.2 Define schedule of verification reporting activities.

Table C-3. Schedule of Verification Reporting Activities

Item	Recommended Time of Submission[a]	[a]Owner's Review and Acceptance Period
Post-Installation Report	30 to 60 days after acceptance	30 days
Annual Report	30 to 60 days after annual performance period	30 days

[a]Times are recommended based on industry practice; modify as needed.

2.3.3 Define content and format of reports:

- Post-installation report.
  — Use Post-Installation Report Outline.[25]
- Annual M&V reports.
  — Use Annual Report Outline.
- Interval M&V reports
  — Develop report outline if needed.

2.4 Operations, Preventive Maintenance, Repair, and Replacement Reporting Requirements

2.4.1 Define government and ESCO reporting requirements:

- Summarize key verification activities and reporting activities of government and ESCO on operations, preventive maintenance, repair, and replacement items from details in ECM-specific M&V plans.

[25] Electronic copies of the *Post-Installation Report Outline* and *Annual Report Outline* are available at http://energy.gov/eere/femp/resources-implementing-energy-savings-performance-contracts.

- Define content of reports and reporting schedule.

2.5 Construction Period Savings

2.5.1 Provide overview of how construction period savings will be calculated, if applicable.

2.6 Status of Rebates

- Include if applicable.

2.6.1 Provide a summary of the source of any third-party rebates or incentives provided on this project.

2.6.2 Provide status of any third-party rebates or incentives.

2.7 Dispute Resolution

2.7.1 Describe plan for resolving disputes regarding issues such as baseline, baseline adjustment, energy savings calculation, and use of periodic measurements.

3. ECM [Name/#] M&V Plan and Savings Calculation Methods

- Develop section for each ECM.

3.1 Overview of ECM, M&V Plan, and Savings Calculation for ECM

3.1.1 Summarize the scope of work, location, and how cost savings are generated.

- Describe source of all savings including energy, water, O&M, and other (if applicable).

3.1.2 Specify the M&V guideline and option used.

3.1.3 Provide an overview of M&V Activities for ECM.

- Explain intent of M&V plan, including what is being verified.

3.1.4 Provide an overview of savings calculations methods for ECM.

- Provide a general description of analysis methods used for savings calculations.

3.2 Energy and Water Baseline Development

3.2.1 Describe in general terms how the baseline for this ECM is defined.

3.2.2 Describe variables affecting baseline energy or water use.

- Include variables such as weather, operating hours, set point changes, etc.
- Describe how each variable will be quantified, i.e. measurements, monitoring, assumptions, manufacturer data, maintenance logs, engineering resources, etc.

3.2.3 Define key system performance factors characterizing the baseline conditions.

- Include factors such as comfort conditions, lighting intensities, temperature set points, etc.

3.2.4 Define requirements for government witnessing of measurements if different than whole project data requirements included in Section 2.3 of this appendix.

3.2.5 Provide details of baseline data collected, including the following.

- Parameters monitored/measured
- Details of equipment monitored, i.e. location, type, model, quantity, etc.
- Sampling plan, including details of usage groups and sample sizes
- Duration, frequency, interval, and seasonal or other requirements of measurements
- Personnel, dates, and times of measurements
- Proof of government witnessing of measurements (if required)
- Monitoring equipment used
- Installation requirements for monitoring equipment (test plug for temperature sensors, straight pipe for flow measurement, etc.)
- Certification of calibration/calibration procedures followed
- Expected accuracy of measurements/monitoring equipment
- Quality control procedures used
- Form of data (.xls, .cvs, etc.)
- Results of measurements (attach appendix and electronic forma as necessary)
- Completed data collection forms, if used

3.2.6 Provide details of baseline data analysis performed, including the following.

- Analysis using results of measurements
- Weather normalized regressions
- Weather data used and source of data

3.3 Proposed Energy and Water Savings Calculations and Methods

3.3.1 Provide detailed description of analysis method used.

- Describe any data manipulation or analysis that was conducted prior to applying savings calculations.

3.3.2 Detail all assumptions and sources of data, including all stipulated values used in calculations.

3.3.3 Include equations and technical details of all calculations made. (Use appendix and electronic format as necessary.) Include description of data format (headings, units, etc.).

3.3.4 Details of any savings or baseline adjustments that may be required.

3.3.5 Detail energy and water rates used to calculate cost savings.

- Provide performance period energy and water rate adjustment factors if different from Section 2.2.2 of this appendix.

3.3.6 Detail proposed annual savings for this energy conservation measure for performance period.

- Summarize information in Table C-4.

3.4 Operations and Maintenance and Other Cost Savings

3.4.1 Provide justification for O&M cost savings, if applicable.

- Describe how savings are generated
- Detail cost savings calculations.
- Provide performance period O&M cost savings adjustment factors if different from Section 2.2.2 of this appendix.

3.4.2 Provide justification for other cost savings, if applicable.

- Describe how savings are generated.
- Detail cost savings calculations.
- Provide performance period adjustment factors if different from Section 2.2.2 of this appendix.

3.5 Proposed Annual Savings for ECM

Table C-4. Proposed Annual Savings for ECM

[Include all applicable fuels/commodities for project, e.g., electric energy, electric demand, natural gas, fuel oil, coal, water, etc.]

	Total energy use (MBtu/ year)	Electric energy use (kWh/ year)	Electric energy cost, Year 1 ($/year)	Electric demand* (kW/year)	Electric demand cost, Year 1 ($/year)	Natural gas use (MBtu/year) *	Natural gas cost, Year 1 ($/year)	Water use (gallons/ year)	Water cost, Year 1 ($/year)	Other energy use (MBtu/ year)	Other energy cost, Year 1 ($/year)	Other energy-related O&M costs, Year 1 ($/year)	Total costs, Year 1 ($/year)
Baseline use													
Post-installation use													
Savings													

Notes

*Annual electric demand savings (kW/year) is the sum of the monthly demand savings. MBtu = 10^6 Btu.
If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to delivery order schedules (e.g., 0.003413 MBtu/kWh).

3.6 Post-Installation M&V Activities

3.6.1 Describe the intent of post-installation verification activities, including what will be verified.

3.6.2 Describe variables affecting post-installation energy or water use.

- Include variables such as weather, operating hours, set point changes, etc.
- Describe how each variable will be quantified, i.e. measurements, monitoring, assumptions, manufacturer data, maintenance logs, engineering resources, etc.

3.6.3 Define key system performance factors characterizing the post-installation conditions such as lighting intensities, temperature set points, etc.

3.6.4 Define requirements for government witnessing of measurements if different than whole project data requirements included in Section 2.3 of this appendix.

3.6.5 Provide details of post-installation data to be collected, including the following.

- Parameters to be monitored
- Details of equipment to be monitored (location, type, model, quantity, etc.)
- Sampling plan, including details of usage groups and sample sizes
- Duration, frequency, interval, and seasonal or other requirements of measurements
- Monitoring equipment to be used
- Installation requirements for monitoring equipment
- Calibration requirements/procedures
- Expected accuracy of measurements/monitoring equipment
- Quality control procedures to be used
- Form of data to be collected (.xls, .cvs, etc.)
- Sample data collection forms (optional)

3.6.6 Detail data analysis to be performed.

3.7 Performance Period Verification Activities

3.7.1 Describe variables affecting performance period energy or water use.

- Include variables such as weather, operating hours, set point changes, etc.
- Describe how each variable will be quantified, i.e. measurements, monitoring, assumptions, manufacturer data, maintenance logs, engineering resources, etc.

3.7.2 Define key system performance factors characterizing the performance period conditions.

- Include factors such as comfort conditions, lighting intensities, temperature set points, etc.

3.7.3 Describe the intent of performance period verification activities, including what will be verified.

3.7.4 Provide detailed schedule of performance period verification activities and inspections.

3.7.5 Define requirements for government witnessing of measurements if different than whole project data requirements included in Section 2.3 of this appendix.

3.7.6 Provide details of performance period data to be collected, including the following.

- Parameters to be monitored
- Details of equipment to be monitored (location, type, model, quantity, etc.)
- Sampling plan, including details of usage groups and sample sizes
- Duration, frequency, interval, and seasonal or other requirements of measurements
- Monitoring equipment to be used
- Installation requirements for monitoring equipment
- Calibration requirements/procedures
- Expected accuracy of measurements/monitoring equipment
- Quality control procedures to be used
- Form of data to be collected (.xls, .cvs, etc.)
- Sample data collection forms (optional)

3.7.7 Detail data analysis to be performed.

3.7.8 Define operations, preventive maintenance, repair, and replacement reporting requirements.

- Detail verification activities and reporting activities of government and ESCO on operations, preventive maintenance, repair, and replacement items.
- Define contents of report and reporting schedule.

APPENDIX D. ESPC POST-INSTALLATION REPORT OUTLINE

[Note: All content called for in this outline is required (if applicable), except items noted as optional.]

Contract #/Delivery Order #/Task #/ Modification #: (include as appropriate)

Performance Period Dates Covered: _____ to _____

1. Executive Summary

1.1 Project Background

1.1.1 Provide an overview of project background, including the following.

- Contract #/Delivery Order #/Task #/Modification # (as appropriate)
- Dates of relevant delivery order modifications
- Performance period dates covered
- Project acceptance date (actual or expected)

1.2 Brief Project and ECM Descriptions

1.2.1 Provide an overview what was done and how savings are generated.

1.2.2 Note any changes in project scope between the final proposal (including any relevant delivery order modifications) and as-built conditions.

1.3 Proposed and expected energy and cost savings for year 1 of the performance period

1.3.1 Compare expected savings for first performance year to first year guaranteed cost savings. State whether guarantee is expected to be fulfilled for first year. If not, provide detailed explanation.

1.3.2 Summarize information in Table D-1 and Table D-2.

Note: Expected savings are prediction for first year based on post-installation M&V activities. Verified savings for first year of performance period will be documented in annual report. The proposed savings for each ECM are included in schedule DO-4 of the delivery order.

Table D-1. Proposed Annual Savings Overview

[Include all applicable fuels/commodities for project, e.g., electric energy, electric demand, natural gas, fuel oil, coal, water, etc.]

ECM	Total energy savings (MBtu/year)	Electric energy savings (kWh/year)	Electric demand savings (kW/year)*	Natural gas savings (MBtu/year)	Water savings (gal/year)	Other energy savings (MBtu/year)	Total energy & water cost savings, Year 1 ($/year)	Other energy-related O&M cost savings, Year 1 ($/year)	Total cost savings, Year 1 ($/year)
Total savings									
First year guaranteed savings: $									

Notes
MBtu=10^6 Btu.
*Annual electric demand savings (kW/year) is the sum of the monthly demand savings.
If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to delivery order schedules (e.g., 0.003413 MBtu/kWh). Guaranteed cost savings for project are defined in schedule DO-1 in delivery order.
The proposed savings for each ECM are included in schedule DO-4 in delivery order.

Table D-2. Expected Savings Overview for First Performance Year

[Include all applicable fuels/commodities for project, e.g., electric energy, electric demand, natural gas, fuel oil, coal, water, etc.]

ECM	Total energy savings (MBtu/year)	Electric energy savings (kWh/year)	Electric demand savings (kW/year)*	Natural gas savings (MBtu/year)	Water savings (gal/year)	Other energy savings (MBtu/year)	Total energy & water cost savings, Year 1 ($/year)	Other energy-related O&M cost savings, Year 1 ($/year)	Total cost savings, Year 1 ($/year)
Total savings									

Notes
MBtu=10^6 Btu.
*Annual electric demand savings (kW/year) is the sum of the monthly demand savings.
If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to delivery order schedules (e.g., 0.003413 MBtu/kWh).

1.4 Energy, Water, and O&M Rate Data

1.4.1 Detail energy and water rates used to calculate cost savings for this period.

1.4.2 Provide performance period rate adjustment factors for energy, water, and O&M cost savings, if used.

1.4.3 Report actual energy and water rates at site for same period (optional).

1.5 Savings Adjustments

1.5.1 Provide summary of any energy and/or cost savings adjustments required between final proposal (including any relevant delivery order modifications) and as-built conditions.

1.5.2 Describe the changes between the final proposal (including any relevant delivery order modifications) and as-built conditions based on post-installation M&V results.

1.6 Construction Period Savings

1.6.1 Provide a summary of construction period savings, if applicable.

1.6.2 Provide overview of how construction period savings are calculated.

1.7 Status of Rebates

- Include if applicable.

1.7.1 Provide a summary of the source of any third-party rebates or incentives provided on this project.

1.7.2 Provide status of any third-party rebates or incentives.

2. ECM [Name/#] M&V Activities and Expected First Year Savings

- Develop section for each ECM.

2.1 Overview of ECM, M&V Plan, and Savings Calculation for ECM

2.1.1 Summarize the scope of work, location, and how cost savings are generated.

- Describe source of all savings including energy, water, O&M, and other (if applicable).

2.1.2 State M&V guideline and option used.

2.1.3 Provide an overview of M&V activities for ECM.

- Explain the intent of M&V plan, including what is being verified.

2.1.4 Provide an overview of savings calculation methods for ECM.

- Provide a general description of analysis methods used for savings calculations.

2.2 Installation Verification

2.2.1 Detail any changes between final proposal (including any relevant delivery order modifications) and as-built conditions.

2.2.2 Provide details of energy and cost savings differences resulting from changes between final proposal (including any relevant delivery order modifications) and as-built conditions based on post-installation M&V results. Summarize information in Table D-3.

2.2.3 Describe construction period savings (if applicable). Include date ECM was in effect and reference acceptance documentation.

2.2.4 Detail savings calculations for construction period savings.

2.3 Post-Installation M&V Activities Conducted

- Detail measurements, monitoring, and inspections conducted in accordance with M&V plan:

2.3.1 Measurement equipment used

2.3.2 Equipment calibration documentation

2.3.3 Dates/times of data collection or inspections, names of personnel, and documentation of government witnessing

2.3.4 Details to confirm adherence to sampling plan

2.3.5 Include all post-installation measured values. Include periods of monitoring and durations and frequency of measurements. (Use appendix and electronic format as necessary). Include description of data format (headings, units, etc.).

2.3.6 Describe how performance criteria have been met.

2.3.7 Detail any performance deficiencies that need to be addressed by ESCO or government.

2.3.8 Note effect of performance deficiencies or enhancements on generation of savings.

Table D-3. Differences in energy and cost savings from changes between final proposal and as-built conditions for ECM

	Total energy savings (MBtu/ year)	Electric energy savings (kWh/ year)	Electric energy cost savings, Year 1 ($/year)	Electric demand savings* (kW/year)	Electric demand cost savings, Year 1 ($/year)	Natural gas savings (MBtu/ year)**	Natural gas cost savings, Year 1 ($/year)	Water savings (gal/year)	Water cost savings, Year 1 ($/year)	Other energy savings (MBtu/ year)	Other energy cost savings, Year 1 ($/year)	Other energy-related O&M cost savings, Year 1 ($/year)	Total cost savings, Year 1 ($/year)
Proposed													
Expected													
Variance													

Notes
MBtu = 10^6 Btu.
*Annual electric demand savings (kW/year) is the sum of the monthly demand savings.
If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to delivery order schedules (e.g. 0.003413 MBtu/kWh).
Note: Expected savings are prediction for first year based on post-installation M&V activities. Verified savings for first year of performance period will be documented in annual report. The proposed savings for each ECM are included in schedule DO-4 of the delivery order.

2.4 Expected Savings Calculations and Methods

2.4.1 Provide detailed description of analysis methods used.

- Describe any data manipulation or analysis that was conducted prior to applying savings calculations.

2.4.2 Detail all assumptions and sources of data, including all stipulated values used in calculations.

2.4.3 Include equations and technical details of all calculations made. (Use appendix and electronic format as necessary.) Include description of data format (headings, units, etc.).

2.4.4 Details of any baseline or savings adjustments made.

2.4.5 Detail energy and water rates used to calculate cost savings.

- Provide performance period energy and water rate adjustment factors, if used.
- Report actual energy and water rates at site for same period (optional).

2.4.6 Detail expected savings for this energy conservation measure for first year.

- Summarize information in Table D-4.

2.5 Details of O&M and Other Savings (if applicable)

2.5.1 Describe source of O&M savings, if applicable.

- Describe verification activities.
- Provide performance period O&M cost savings adjustment factors, if applicable.

2.5.2 Describe source of other savings, if applicable.

- Describe verification activities.
- Provide performance period adjustment factors, if applicable.

Note: Expected savings are prediction for first year based on post-installation M&V activities. Verified savings for first year of performance period will be documented in the annual report. The proposed savings for each ECM are included in schedule TO-4 of the delivery order.

Table D-4. Expected Year 1 Savings for ECM

[Include all applicable fuels/commodities for project, e.g., electric energy, electric demand, natural gas, fuel oil, coal, water, etc.]

	Total energy use (MBtu/ year)	Electric energy use (kWh/ year)	Electric energy cost ($/year)	Electric demand* (kW/year)	Electric demand cost ($/year)	Natural gas use (MBtu/ year)	Natural gas cost ($/year)	Water use (gal/year)	Water cost ($/year)	Other energy use (MBtu/year)	Other energy cost ($/year)	Other energy-related O&M costs ($/year)	Total costs ($/year)
Baseline use													
Post-installation use													
Savings													

Notes
MBtu = 10^6 Btu.
*Annual electric demand savings (kW/year) is the sum of the monthly demand savings.
If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to delivery order schedules (e.g. 0.003413 MBtu/kWh).

APPENDIX E. ESPC ANNUAL REPORT OUTLINE

[Note: All content called for in this outline is required (if applicable), except items noted as optional.]

Contract #/Delivery Order #/Task #/ Modification #: (include as appropriate)

Performance Period Dates Covered: _____to_____

1. Executive Summary

1.1 Project Background

1.1.1 Provide an overview of project background, including the following

- Contract #/Delivery Order #/Task #/Modification # (as appropriate)
- Dates of relevant delivery order modifications
- Performance period dates covered
- Project acceptance date

1.2 Brief Project and ECM Descriptions

1.2.1 Provide an overview what was done and how savings are generated.

1.2.2 Note any changes in project scope between the final proposal (including any relevant delivery order modifications) and as-built conditions as recorded in post-installation report.

1.3 Summary of Proposed and Verified Energy and Cost Savings

1.3.1 Compare verified savings for performance year # to guaranteed cost savings for year #. State whether guarantee is fulfilled for year. If not, provide detailed explanation.

1.3.2 Define performance period.

1.3.3 Summarize information in Tables E-1 through E-3.

Table E-1. Proposed Annual Savings Overview

[Include all applicable fuels/commodities for project, e.g., electric energy, electric demand, natural gas, fuel oil, coal, water, etc.]

ECM	Total energy savings (MBtu/year)	Electric energy savings (kWh/year)	Electric demand savings (kW/year)*	Natural gas savings (MBtu/year)	Water savings (gal/year)	Other energy savings (MBtu/year)	Total energy & water cost savings, Year # ($/year)	Other energy-related O&M cost savings, Year # ($/year)	Total cost savings, Year # ($/year)
Total Savings									
Year [#] guaranteed cost savings: $									

Notes
MBtu = 10^6 Btu.
*Annual electric demand savings (kW/year) is the sum of the monthly demand savings.
If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to delivery order schedules (e.g., 0.003413 MBtu/kWh).
Guaranteed cost savings for project are defined in cost schedule DO-1 in delivery order. The proposed savings for each ECM are included in schedule DO-4 in the delivery order.

Table E-2. Verified Savings for Performance Year [#]

[Include all applicable fuels/commodities for project, e.g., electric energy, electric demand, natural gas, fuel oil, coal, water, etc.]

ECM	Total energy savings (MBtu/year)	Electric energy savings (kWh/year)	Electric demand savings (kW/year)*	Natural gas savings (MBtu/year)	Water savings (gal/year)	Other energy savings (MBtu/year)	Total energy & water cost savings, Year # ($/year)	Other energy-related O&M cost savings, Year # ($/year)	Total cost savings, Year # ($/year)
Total savings									

Notes
MBtu = 10^6 Btu.
*Annual electric demand savings (kW/year) is the sum of the monthly demand savings.
If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to delivery order schedules (e.g. 0.003413 MBtu/kWh).

Table E-3. Summary of Cost Savings Impact Due to Performance and O&M Issues

Per M&V Plan and RRPM Matrix	($)	Responsibility
Proposed Cost Savings		ESCO
Verified Cost Savings		ESCO
Guaranteed Cost Savings		ESCO
Variance (Verified − Guaranteed)		ESCO
Government Impact to Savings		
Government Impact on ECMs (Lost cost savings)		Government
Net Cost Savings to Government (Verified- Government Impact)		
Net Variance (Net Cost Savings – Guaranteed)		

1.4 Savings Adjustments

- Provide summary of any energy and/or cost savings adjustments required.

1.5 Performance and O&M Issues

- Note effect of operating deficiencies or enhancements on generation of savings.
- Note effect of maintenance deficiencies on generation of savings.
- Detail any deficiencies that need to be addressed by ESCO or government in Table E-4.

Table E-4: Detail of Cost Savings Impact due to Performance and O&M Issues

ECM #	Impact to Cost Savings ($)	ECM Location	Cause of Savings Impact	Responsibility (ESCO/Government)

1.6 Energy, Water, and O&M Rate Data

1.6.1 Detail energy and water rates used to calculate cost savings for this period.

1.6.2 Provide performance period rate adjustment factors for energy, water, and O&M cost savings, if used.

1.6.3 Report actual energy and water rates at site for same period (optional).

1.7 Verified Savings to Date

- Summarize information in Table E-5.

2. Details for ECM [name/#]

- Develop section for each ECM.

2.1 Overview of ECM, M&V Plan, and Savings Calculation for ECM

2.1.1 Summarize the scope of work, location, and how cost savings are generated.

- Describe source of all savings including energy, water, O&M, and other (if applicable).

2.1.2 Discuss any changes in scope/results recorded in post-installation M&V report.

2.1.3 State M&V guideline and option used.[26]

2.1.4 Provide an overview of M&V activities for ECM.

- Explain the intent of M&V plan, including what is being verified.

2.1.5 Provide an overview of savings calculation methods for ECM.

- Provide a general description of analysis methods used for savings calculations.

2.2 M&V Activities Conducted This Period

- Detail measurements, monitoring, and inspections conducted this reporting period in accordance with M&V plan.

2.2.1 Measurement equipment used

2.2.2 Equipment calibration documentation

[26] M&V options include A, B, C, and D (see Section 4). Guidelines include the *International Performance Measurement & Verification Protocol* (IPMVP), Volume I (http://www.evo-world.org/index.php?lang=en).

Table E-5. Verified Savings for Performance Period to Date

[Include all applicable fuels/commodities for project, e.g., electric energy, electric demand, natural gas, fuel oil, coal, water, etc.]

Year #	Total energy savings (MBtu/year)	Electric energy savings (kWh/year)	Electric demand savings (kW/year)*	Natural gas savings (MBtu/year)	Water savings (gal/year)	Other energy savings (MBtu/year)	Total energy & water cost savings ($/year)	Other energy-related O&M cost savings ($/year)	Total cost savings ($/year)	Guaranteed cost savings for year
Total savings										

Notes

MBtu = 10^6 Btu.

*Annual electric demand savings (kW/year) is the sum of the monthly demand savings.

If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to cost schedules (e.g., 0.003413 MBtu/kWh).

2.2.3 Dates/times of data collection or inspections, names of personnel, and documentation of government witnessing

2.2.4 Details to confirm adherence to sampling plan

2.2.5 Include all measured values for this period. Include periods of monitoring and durations and frequency of measurements. (Use appendix and electronic format as necessary). Include description of data format (headings, units, etc.).

2.2.6 Describe how performance criteria have been met.

2.2.7 Detail any performance deficiencies that need to be addressed by ESCO or government.

2.2.8 Note effect of performance deficiencies or enhancements on generation of savings.

2.3 Verified Savings Calculations and Methods

2.3.1 Provide detailed description of analysis methods used.

- Describe any data manipulation or analysis that was conducted prior to applying savings calculations.

2.3.2 Detail all assumptions and sources of data, including all stipulated values used in calculations.

2.3.3 Include equations and technical details of all calculations made. (Use appendix and electronic format as necessary.) Include description of data format (headings, units, etc.).

2.3.4 Details of any baseline or savings adjustments made.

2.3.5 Detail energy and water rates used to calculate cost savings.

- Provide performance period energy and water rate adjustment factors, if used.
- Report actual energy and water rates at site for same period (optional).

2.3.6 Detail verified savings for this energy conservation measure for performance year.

- Include Table E-6.

2.4 Details of O&M and Other Savings (if applicable)

2.4.1 Describe source of savings, if applicable.

- Describe verification activities.
- Provide performance period O&M savings adjustment factors, if applicable.

Table E-6. Verified Annual Savings for ECM for Performance Year #

[Include all applicable fuels/commodities for project, e.g., electric energy, electric demand, natural gas, fuel oil, coal, water, etc.]

	Total energy use (MBtu/ year)	Electric energy use (kWh/ year)	Electric energy cost, Year # ($/year)	Electric demand* (kW/year)	Electric demand cost, Year # ($/year)	Natural gas (MBtu/ year)*	Natural gas cost, Year # ($/year)	Water use (gal/year)	Water cost, Year # ($/year)	Other energy use (MBtu/ year)	Other energy cost, Year # ($/year)	Other energy-related O&M costs, Year # ($/year)	Total costs, Year # ($/year)
Baseline use													
Performance Year # use													
Savings													

<u>Notes</u>
MBtu = 10^6 Btu.
*Annual electric demand savings (kW/year) is the sum of the monthly demand savings.
If energy is reported in units other than MBtu, provide a conversion factor to MBtu for link to cost schedules (e.g., 0.003413 MBtu/kWh).

2.4.1 Describe source of other savings, if applicable.

- Describe verification activities.
- Provide performance period adjustment factors, if applicable.

2.5 O&M and Other Activities

2.5.1 Operating requirements include the following.

- State organizations that will perform measurement and verification of equipment operations. If appropriate, detail how such activities are shared.
- Summarize key operating procedures and any related verification activities.
- Detail any deficiencies that need to be addressed by ESCO or government.
- Note effect of operating deficiencies or enhancements on generation of savings.

2.5.2 Preventive maintenance requirements include the following.

- State organizations that will perform maintenance. If appropriate, detail how such activities are shared.
- Verification of scheduled maintenance items completed by ESCO or government.
- Detail any deficiencies that need to be addressed by ESCO or government.
- Note effect of maintenance deficiencies on generation of savings.

2.5.3 Repair and replacement requirements include the following

- State organizations that will perform repair and replacement. If appropriate, detail how such activities are shared.
- Summary of activities conducted this period by ESCO or government.
- Detail any deficiencies that need to be addressed by ESCO or government.
- Note effect of equipment deficiencies on generation of savings.

FEMP provides a wealth of guidance on all phases of ESPC projects on its web page at http://energy.gov/eere/femp/resources-implementing-energy-savings-performance-contracts. While developed for federal ESPCs in particular, much of the guidance will be of use to any ESPC customer. Documents specifically related to M&V include the following:

Example M&V Plan for an ESPC Project,
http://energy.gov/sites/prod/files/2013/10/f3/sample_mv_plan.pdf

How to Determine and Verify Operating and Maintenance (O&M) Savings in Federal Energy Savings Performance Contracts,
www1.eere.energy.gov/femp/pdfs/10_4_determineverifyomsavings.pdf

Reviewing Measurement & Verification Plans for Federal ESPC Projects
www1.eere.energy.gov/femp/pdfs/6_3_reviewingmvplans.pdf

Reviewing Post-Installation and Annual Reports For Federal ESPC Projects
www1.eere.energy.gov/femp/docs/reviewing_annual_pi_reports.doc

Including Retrocommissioning in Federal Energy Saving Performance Contracts
www1.eere.energy.gov/femp/pdfs/11_2_includingretrocommissioning.pdf

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