Performance-Based Measurement and Verification Guidelines

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Ahmad Hammouz, P.Eng., LEED AP

Continuing Education and Development, Inc.

P: (877) 322-5800
info@cedengineering.ca

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Updates to Version 5.0

This document updates the previous version of the FEMP M&V Guidelines: Measurement and Verification for Performance-Based Contracts Version 4.0, released in November 2015. Edits to the previous version include clarification on the application of measurement and verification (M&V) options used in performance-based projects, based on DOE FEMP ESPC program review and feedback from stakeholders, and a reorganization of and additions to Section 6.0: Guidance for Specific ECMs. The appendices reflect DOE ESPC IDIQ program-specific outline updates for the required M&V plan, post-installation report and annual report. Similarly, the Risk Responsibility and Performance Matrix (RRP Matrix) has been updated to reflect the most recent version (2023) of the DOE ESPC IDIQ contract requirements. These guidelines remain applicable to all performance-based contracts.

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1 Introduction

1.1 PURPOSE OF THE FEMP M&V GUIDE

This document contains procedures and guidelines for verifying and quantifying the savings resulting from energy -efficient 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) implements energy or water conservation measures at a customer's facility and guarantees or assures a level of facility performance (e.g., light levels and temperatures in the space) and the resulting level of energy, water, and energy- and water-related cost savings. Common types of performance-based contracts include energy savings performance contracts (ESPC) and utility energy service contracts (UESC), the latter of which is a federal contracting vehicle in which energy services are provided through the serving utility. In this document, the term "performance-based contract" refers to both ESPCs and UESCs, similarly the term "contractor" means "ESCO" or "utility."

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

- It serves as a reference document for specifying M&V methods and procedures.
- It is a resource for 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 is on performance-based contracts, the procedures can be adapted to determine savings from conservation measures installed in any project, regardless of funding source.

Federal ESPCs awarded under the DOE ESPC IDIQ contract are required to follow the latest FEMP M&V Guidelines. Individual federal agencies may have complementary and supplemental requirements for verifying and reporting savings.

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) by the Efficiency Valuation Organization (EVO®) and American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Guideline 14, *Measurement of Energy, Demand, and Water Savings*.[1,2] These two guidelines are described below. For additional reference, the DOE Uniform Methods Project is

[1] International Performance Measurement and Verification Protocol: Core Concepts, EVO-10000-1.2022, Efficiency Valuation Organization.
[2] ASHRAE Guideline 14-2023: Measurement of Energy, Demand and Water Savings, American Society of Heating, Refrigerating, and Air Conditioning Engineers.

included in this section as it provides a set of protocols for evaluating energy efficiency measures, though directed at state and utility programs.

1.2.1 IPMVP

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

Developed through a collaborative effort involving industry, government, financial, and other organizations, the IPMVP provides four M&V options and addresses issues related to the use of M&V in third party-financed and utility projects across several reference documents (IPMVP Core Concepts and accompanying application guides).

The FEMP M&V Guidelines contain specific procedures for applying concepts originating in the IPMVP Core Concepts and represents a specific application of the IPMVP, outlining 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 address other issues related to performance contracting (e.g., determination of appropriate utility rates, installation of equipment).

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 has developed a set of protocols for determining savings from energy efficiency measures implemented through state and utility 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. Each of the measure protocols are based on a particular IPMVP option but include additional procedures necessary to aggregate savings from individual projects in order to evaluate program-wide impacts. The UMP protocols are updated on an as-needed basis.

For commercial measures, the FEMP guidelines 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

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

performance, the FEMP guidelines include additional recommendations for annual inspection and measurements, where appropriate.

2 Overview of Measurement & Verification

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 energy conservation measures[4]. Energy savings may include energy, demand, and water savings, while energy- and/or water-related savings may include O&M savings. 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 and water savings and persistence of savings for a project.
- Determine whether savings and facility performance guarantees have been realized.
- Manage uncertainties to reasonable levels.
- Monitor equipment performance to identify potential issues.
- Identify additional savings opportunities.
- Improve operations and maintenance (O&M).

2.1 GENERAL APPROACH TO M&V

M&V is the process of quantifying the energy or water performance and cost savings resulting from improvements in energy- or water-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.

2.1.1 Determining Savings

Typically, savings cannot be measured directly because the savings represent the absence of energy or water use and related expenditures. Savings are determined by comparing resource use before and after the installation of ECMs and making appropriate adjustments for changes in conditions which may be referred to as avoided energy use. Consequently, it should be understood that there is a certain level of uncertainty in savings estimates. The goal of M&V is to reduce the uncertainty to an acceptable level.

The “before” case is called the baseline. The “after” case (i.e., after ECMs have been installed) 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 and outside the contractor’s control.

[4] For the purpose of this document, energy and water conservation or efficiency measures are collectively referred to as ECMs. See Appendix A: Glossary for statutory criteria for federal ESPCs.

Equation 2-1 shows the general equation used to calculate savings.

Equation 2-1. General Equation Used to Calculate Savings

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

In the early days of the energy services industry, comparison of baseline and performance-period utility bills was the most common method of M&V.[5] While this method proved adequate in the short-term, it often led to difficulties in buildings and multi-building 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 ECMs and the equipment they replaced.

Two fundamental factors drive energy savings associated with an ECM: energy performance and usage.[6] Energy performance describes the rate at which energy is used to accomplish a specific task (e.g., for electricity watts); usage describes how much of the task is required (e.g., operating hours of specific equipment). For example, in the simple case of lighting, energy performance is the power (kW) required to provide a specific light level on a given surface, and usage is the operating hours per year (hours). For a chiller (a more complex system), energy performance is defined as the energy required to provide a specific amount of cooling (kW) (which varies with load – kW/ton), whereas usage is defined by the cooling load profile and the total amount of cooling required. Both energy performance and usage factors need to be known to determine baseline and post-retrofit energy consumption in order to calculate savings, as shown in Figure 2-1.

[5] 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 https://oaktrust.library.tamu.edu/handle/1969.1/2049

[6] For the remainder of this guidance "energy performance and use" includes "water performance and use" and "water."

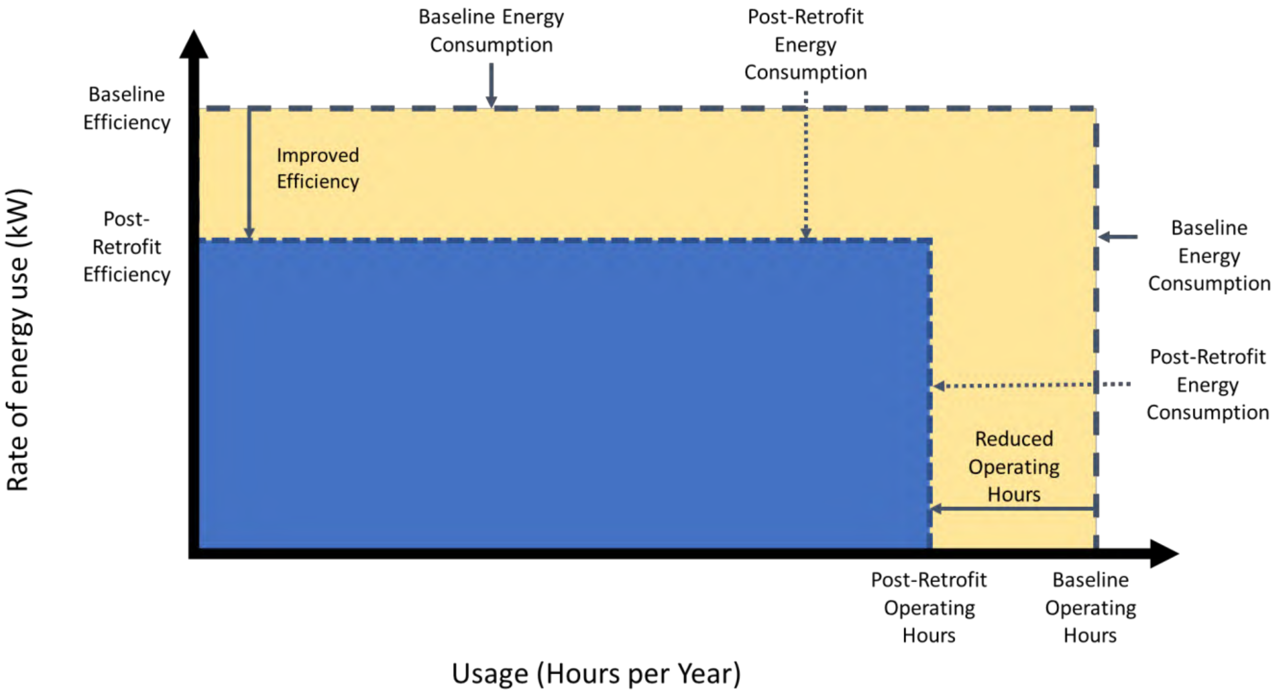

Figure 2-1. Energy Savings Depend on Performance and Usage

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

Baseline and performance period energy use can be determined by using the methods associated with four M&V options. These options, originating in the IPMVP, are termed options A (Retrofit Isolation with Key Parameter(s) 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 and are dependent on the complexity of the project, the potential for changes in facility performance, the level of savings contributed by each ECM, and the allocation of risk between the contractor and the customer for the project.

An important consideration in setting energy baselines for the equipment (or facility, if whole-building M&V is anticipated) is the duration of the baseline measurement period or periods. The baselines should represent current and planned normal operations and are typically established just before project award. Utility bills from the previous 12 to 36 months should be reviewed to determine any anomalies and/or seasonal variations. To ensure accuracy of the baseline at reasonable cost, the measurement period should be sufficient to capture performance across the full range of operating conditions and seasonal variations for any equipment under consideration for inclusion in the project.

2.1.2 Adjustments

Adjustments are used to account for changes in operating conditions to ensure an appropriate comparison of energy consumption between the baseline and post installation and performance periods. These can be routine adjustments or non-routine adjustments (NRAs). Routine adjustments account for expected variations in independent variables (*variables expected to change that may have a measurable impact on the energy consumption*) like weather. NRAs may be necessary to account for significant unexpected changes in energy use due to changes to static factors (*factors within the defined measurement boundary that are not expected to change during the performance period*) like occupancy, operating hours, etc. that were not anticipated during the IGA.

To account for changes in the operating conditions or structural or operational changes impacting energy or water usage at a facility between the baseline and the post installation or performance periods, adjustments may need to be made. These adjustments can be made to either baseline or post-installation period energy or water usage to ensure the comparisons between the baseline and post retrofit usages are sensible. Therefore, savings can be represented by the following equation 2-2:

Equation 2-2. Equation Used to Calculate Savings, Accounting for Routine, Non-Routine Adjustments

Savings = (Baseline Energy − Post Installation or Performance Period Energy) ± Routine Adjustments ± Non-routine Adjustments

Refer to the FEMP Supplement to these M&V Guidelines for more information on adjustments.

2.1.3 Routine Adjustments

Routine adjustments and the methodology for applying routine adjustments during the period of performance are determined in the project-specific M&V plan prior to task order award. Routine adjustments are used to account for expected variations in independent variables and energy use for meter-based M&V options (IPMVP Options B and C) within the measurement boundary. These adjustments often use regression analysis to correlate and adjust energy use to independent variables to normalize energy use as a function of one or more independent parameters such as weather, meals served, production, or any other factor that varies periodically.

These adjustments allow the normalization of energy usage by ensuring the same set of conditions between the baseline and performance periods, such as characteristic weather conditions (e.g., TMY weather data) and the corresponding load profile, thereby allowing the risks associated with these factors to be managed appropriately.

Take for example an ECM replacing an old, inefficient chiller with a more efficient chiller. This ECM is evaluated using Option B based on the energy consumption which depends on the load on the chiller. One of the major factors that impact the load on the chiller is the outside weather conditions. A model is developed that can be used to conduct routine adjustments to account for weather conditions that correlates outside air temperature with the kW drawn by the chiller.

2.1.4 Non-Routine Adjustments

Non-routine adjustments (NRAs) are used to account for unexpected changes in energy usage impacted by variables other than the ones used to conduct routine adjustments as described above. These variables such as facility size and usage– referred to as "static" factors – are assumed to stay constant between the baseline and performance period. These static factors should be monitored to ensure that they are not changing, however changes resulting from a non-routine event (NRE) could affect the savings associated with the ECM(s). NRAs are primarily a concern for projects employing whole-building M&V options (Options C & D), but may also apply for Option B. Option A typically avoids these types of adjustments as the ECM is being evaluated in isolation, and many of these static factors (such as hours of operation) are contractually agreed to by the customer and contractor, documented as part of the M&V plan.

The M&V plan should list all the possible static factors that might affect the ECM's savings and thresholds for what triggers an NRA, along with a discussion on the methodology for making these NRAs. For example, consider a demand-controlled ventilation ECM, which brings in outside air based on the occupancy in the zone. The NRE is that the facility added more occupants to the space during the performance period than were accounted for in the savings calculations during the IGA. As a result, the energy consumption from the RTU increased because of the increased demand for HVAC thereby appearing to negatively affect the savings associated with this ECM. The energy savings is accounted for through an NRA for this increased occupancy by making the necessary baseline adjustments before comparing with the actual energy consumption during the performance period.

When conducting M&V activities and unexpected change(s) occurs that is not factored in the original M&V plan, then it is determined whether there is an NRE that warrants revisiting the M&V plan and energy or water baseline. Techniques to detect NREs along with when and how to account for NRAs for performance contracts will be discussed in detail in the FEMP Supplement to these M&V Guidelines. Additional information on NREs and developing techniques for NRA is available in publications such as *IPMVP Application Guide on Non-Routine Events & Non-Routine Adjustments*. The magnitude of impact on the overall project and associated cost savings determines whether an adjustment is warranted.

2.1.5 Weather Data in M&V

Weather often plays an important role in energy baselines and estimated savings. "Typical meteorological year" (TMY) provides industry standard weather files for calculating energy baselines and estimating savings. TMY datasets are intended to represent the long-term typical meteorological conditions at a specific location by taking into account time series data across many years and converting that into a one-year representative dataset. TMY represents weather data for a specific location with hourly values for a specific location that indicate mean and median monthly weather conditions over a multi-year period. TMY datasets are not used to predict weather for a particular period of time but rather to characterize seasonal and daily weather trends.[7] The data sets are typically

[7] https://www.nrel.gov/docs/fy08osti/43156.pdf

available from commercial and public databases such as the National Solar Radiation Data Base (NSRDB)[8]. In the NSRDB, there are three generations of TMY datasets: TMY2 (created using data from 1961 – 1990), and TMY3 (created using data from 1991 – 2005), and gridded TMY[9] (created from 1998 – present year with one year lag). TMY datasets can be customized to capture a multiyear and recent year dataset. The range of years of the long-term time series that was used to produce TMY should be specified. There has been a shift in more recent TMY data, with generally increasing numbers of cooling degree days (CDD) and decreasing heating degree days (HDD).[10]

TMY datasets use a specific methodology and format and are often used in energy calculations when evaluating projects or measures (for all M&V options). Actual weather data files may be used in calibrating building simulation models to match meteorological conditions to energy usage during a specific time period. However, TMY datasets are used in projecting energy usage over the ESPC contract term as they represent more characteristic or standard conditions and therefore normalize the weather data and energy savings.

2.2 STEPS TO DETERMINE AND VERIFY SAVINGS

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

2.2.1 Step 1: Define Baseline(s)

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 a variety of methods, including surveys, inspections, spot measurements, and short-term metering or measurement activities. Utility bills may be used to verify that baselines have been accurately defined depending on the M&V method. Baseline conditions are established by defining equipment operating parameters and energy use for the purpose of estimating savings (through comparing the baseline energy use with the post-installation energy use). Baseline information is also used to identify any changes that occur during the performance period, which may require baseline adjustments. Refer to the FEMP Supplement to these M&V Guidelines for more information on adjustments.

Baseline data should reflect the most relevant building operating conditions and be collected for a period just before contract award. The length of the baseline period may vary based on the equipment surveyed or the level of existing building energy and water metering. Baseline data should be gathered for enough time to clearly define equipment performance, such as measuring chiller performance through a full range of loads during the cooling season (as opposed to spot-metering a constant speed motor that operates a set number of hours per week) and should be compared to several years of utility billing data to determine potential impact on overall building energy consumption. Baseline data may include available information on specific equipment operation (e.g.,

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[8] https://nsrdb.nrel.gov/

[9] Historically, TMY data sets were only available for certain station locations, but gridded TMY data sets are available on the same grid as the NSRDB.

[10] https://www.epa.gov/climate-indicators/climate-change-indicators-heating-and-cooling-degree-days

boiler or chiller logs, building automation system trend data), or this may need to be collected via short-term metering.

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

2.2.2 Step 2: Determine ECMs to Include in Project

It is the contractor's responsibility to determine cost-effective ECMs that can be included in a project, based on baseline energy use, customer guidance, facility requirements and equipment replacement needs. The customer's responsibility is to provide the contractor with access to the facility and any information or support needed to develop an investment grade audit (IGA). The M&V plan will be developed based on the complexity and savings associated with each ECM.

2.2.3 Step 3: Allocate Project Risks and Responsibilities

The basis of any project M&V plan is determined by the allocation of key project risks and responsibilities between the contractor and the customer. Several 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 consistent with the statutory authority will depend on the customer's resources and preferences, and the contractor's ability to control certain factors.

2.2.4 Step 4: Develop a Project-Specific M&V Plan

The project M&V plan is the primary vehicle that a customer uses to first document and then to periodically evaluate the performance of the project. The M&V plan defines how savings will be calculated and specifies any ongoing activities that will occur after equipment installation. This includes defining the measurement boundary for ECM-level or project-wide items, whichever is deemed most appropriate when determining the M&V option(s), and clearly documenting any assumptions used and sources of savings. The project M&V plan includes project-wide items as well as details for each ECM.

Project-wide items include the following:

- Overview of estimated energy and cost savings, and guaranteed cost savings.
- Schedule for all M&V activities.
- Witnessing requirements and customer approval and sign-off requirements.
- Utility rates and the method used to calculate cost savings.
- O&M reporting responsibilities.

ECM-level items include the following details:

- Baseline conditions and data collected.
- Documentation of all assumptions and sources of data.
- Engineering analysis performed.
- How energy savings will be calculated.
- Any O&M or other cost savings claimed.
- Estimated energy and cost savings.
- Post-installation verification activities, including inspections, witnessing, measurements, analysis and customer project acceptance procedures.
- Performance-period verification activities, including inspections, witnessing, measurements, analysis/calculations, and reporting schedule.
- Any anticipated adjustments to baseline or reporting period energy savings, adjustment parameters, and justification for any adjustments.
- Content and format of all required M&V reports (post-installation and performance period M&V).

For federal ESPCs, if operation and maintenance savings are included in the project, then the contractor will use with the latest version of "How to Determine and Verify Operating and Maintenance (O&M) Savings in Energy Savings Performance Contracts".

A sample M&V plan outline, required for federal ESPCs under the DOE ESPC IDIQ contract and used under the U.S. Army Corps of Engineers (USACE) multiple award task order contract (MATOC), is provided in Appendix C. This may also be applicable for performance contracts in other sectors.

2.2.5 Step 5: Install and Commission Equipment and Systems

Commissioning of installed equipment and systems is considered industry best practice. FEMP's Commissioning for Federal Facilities describes commissioning as "a method of risk reduction," and a "systematic process of ensuring that all building systems perform interactively according to the design intent and Owner's operational needs…to ensure that they function efficiently, and as designed, as a system."[11] ASHRAE Guideline 0, *The Commissioning Process*,[12] defines commissioning as "a quality-focused process for enhancing the delivery of a project by achieving, validating, and documenting the performance of facility elements in meeting the owner's objectives and criteria." 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, space temperatures, etc.). A 30-day proof of

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[11] FEMP, Commissioning for Federal Facilities, U.S. Department of Energy, Energy Efficiency and Renewable Energy, 2014.

[12] ASHRAE, *The Commissioning Process*, ASHRAE Guideline 0-2019 (supersedes ASHRAE Guideline 0-2013 and 0-2005), the American Society of Heating, Refrigerating, and Air Conditioning Engineers, 2019.

performance may be required by the customer to ensure systems are operating correctly for a specified duration (i.e., 30 days) prior to acceptance.

Commissioning usually requires functional performance testing 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 installed per design criteria and functioning properly, whereas post-installation M&V quantifies how well the systems are working from an energy standpoint in support of expected cost savings.

2.2.6 Step 6: 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 estimated savings. The post-installation report presents the expected savings for the first year of performance; the verified Year 1 savings does not occur until after the first year of performance and is presented in the Year 1 annual M&V report.

Verification methods include surveys, inspections, spot measurements, and short-term metering.

A post-installation M&V report is a key deliverable in a performance-based contract. 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, including customer witnessing of these activities.
- Performance verification—how performance criteria were met.
- Documentation of construction-period savings (if any)
- Status of rebates or other incentives (if any)
- Expected savings for the first year.

An outline for the post-installation report, required for federal ESPCs under the DOE ESPC IDIQ contract and US Army Corps of Engineers (USACE) multiple award task order contract (MATOC), is provided in Appendix D.

2.2.7 Step 7: Perform Regular-Interval M&V Activities

M&V activities must be performed at regular intervals to ensure that the installed equipment is operational and is delivering the savings that were guaranteed. In federal ESPC projects, M&V is required to be performed on an annual basis at a minimum. Other requirements for federal ESPCs are outlined in Appendix B, and other sectors or jurisdictions may have their own requirements. Operational performance verification is an important part of the periodic M&V process. With proper coordination and planning, M&V activities that provide operational performance 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). In the context of ESPC, where one of the objectives is to provide guaranteed cost savings, ongoing commissioning to monitor and sustain ECM performance 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).

Periodic reports document annual M&V activities and report verified and guaranteed savings for each performance year. In federal ESPC projects, an annual report is required to document annual M&V activities and government witnessing of those activities, and report verified cost savings for each performance period. There may be cases when more frequent verification activities are appropriate. More frequent monitoring and/or inspection ensures that the M&V monitoring and reporting systems are working properly, installed equipment and systems are operating as intended, allows fine-tuning of measures throughout the performance year based on operational feedback, and avoids surprises at the end of each performance period.

Annual reports in federal ESPC projects include the following for each ECM:

- Results/documentation of performance measurements and inspections, including customer witnessing of these activities.
- Verified savings for the year (energy, energy costs, O&M costs, etc.)
- Details of all analysis and savings calculations, including commodity rates used and any adjustments performed.
- Summary of operations and maintenance activities conducted.
- Details of any performance or O&M issues that require attention.
- Impacts of customer actions (e.g., O&M, government impacts) on ECM performance[13]
- Comparison of verified savings with the guaranteed amounts for the project

An outline for the Annual M&V Report, required for federal ESPCs under the DOE ESPC IDIQ contract and USACE MATOC, is provided in Appendix E.

[13] Government impact to savings captured in tables E-3 and detailed in E-4 of the Annual M&V Report (see Appendix E).

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 any performance contract, project risks and responsibilities are allocated between the contractor and the customer. In the context of M&V, the word "risk" refers to the uncertainty that the expected performance and savings will be realized, including the potential monetary consequences.

The allocation of responsibilities between the contractor and the customer drives the M&V strategy, which actually defines the specifics of how fulfillment of the savings guarantees, or performance assurance will be determined. Both the contractor and the customer may be 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.
- Agreeing to (i.e., stipulating) certain fixed 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 contractors often have no control over such factors, they are usually reluctant to assume usage risk. The customer generally assumes 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 fixed (i.e., stipulated) parameters means that the contractor 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. It is critical to note that stipulation is for individual parameters only and is prohibited by the IPMVP for savings associated with the entire ECM. 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 (RRP Matrix) is required for ESPC projects awarded under the DOE ESPC IDIQ contract and is a useful tool for considering the risks in any performance-based project. This matrix summarizes 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 RRP Matrix. Early in the project development process, the contractor and the customer review the RRP Matrix and evaluate how to allocate the key responsibilities.

A sample RRP Matrix template, shown in Table 3-1, describes typical financial, operational, and performance risks and their influence on performance contracts (each of these risk categories has several subcategories). The table lists the primary factors that affect achieving, sustaining, and determining savings and illustrates how their definition indicates which party—the contractor, customer, or perhaps neither—will assume or manage the risks for each factor.

Financial risk includes risk of savings shortfalls, as well as risks of unforeseen changes in construction costs or schedule, addressing hazardous materials, future facility changes, and energy prices including annual escalation rates. To assist in the determination of energy escalation rates, DOE has created the Energy Escalation Rate Calculator (EERC) tool, which can calculate a single appropriate escalation rate to use over the entire contract term. The EERC is available on-line from the National Institute of Standards and Technology (NIST) website[14], and available on the FEMP Energy Management Tools web page[15], as is FEMP's guidance on escalation rates.[16]

Operational risk results from factors generally out of the contractor's control that may affect energy use and savings, such as facility operating hours, equipment loads, and weather.

Performance risk is the uncertainty associated with the ability of an ECM to both achieve savings and also meet contractually required facility conditions (such as temperature setpoints and lighting levels).

For federal ESPC projects, the RRP Matrix is first included in the preliminary assessment as part of the project management plan and is finalized in the final proposal. A blank column in the RRP Matrix is completed by the contractor 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 contractor and agency.

Completing the RRP Matrix serves as a useful exercise in understanding the approaches required in the M&V plan because the matrix indicates what activities the contractor and/or customer will perform or oversee and thus need to be documented during the life of the contract. The allocation of

[14] https://pages.nist.gov/eerc/
[15] https://www.energy.gov/femp/federal-energy-management-tools
[16] https://www.energy.gov/femp/articles/guidance-utility-rate-estimations-and-weather-normalization-performance-contracts

risk and/or responsibility must take into account the customer's resources and preferences and the contractor's ability to control certain factors. In general, a contract objective may be to release the contractor from responsibility for factors beyond its control, such as building occupancy, energy prices, and weather[17], yet hold the contractor responsible for controllable factors (risks) such as sustained equipment efficiency and availability.

The contractor 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. The responsibilities, agreements, and other information associated with the operations, preventive maintenance, and repair and/or replacement of ECMs are summarized in the RRP Matrix.

Table 3-1. Sample Performance Contract Risk, Responsibility, and Performance Matrix Template[18]

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 contract award signing may impact the available interest rate and project cost. **Clarify how the project interest rate will be determined and when it will be locked.**	
b. Energy/Water Prices: Neither the contractor nor the customer has significant control over actual energy or water prices, which tend to fluctuate over time. For calculating savings, the value of the saved energy or water may either be constant, change at a fixed inflation rate, escalate at an agreed-upon rate(s), or float with market conditions. If the value changes with the market, falling energy or water prices place the contractor at risk of failing to meet cost savings guarantees. If energy or water prices rise, there is a small risk to the customer that energy or water saving goals might not be met while the financial goals are. If the value of saved energy or water is fixed (either constant or escalated), the customer risks making payments in excess of actual energy or water cost savings (conversely, the customer could realize *excess* savings if actual rates exceed contractual rates). **Clarify how energy or water prices will be valued over time for the purpose of calculating cost savings.**	
c. Construction/Project Implementation costs: The contractor is responsible for determining construction/project implementation costs and defining a budget. In a fixed-price design/build contract, the contractor generally assumes responsibility for cost overruns (except in instances where the customer causes delays). However, if construction/project implementation estimates are significantly greater than originally assumed, the contractor may find that the project or measure is no longer viable and drop it before contract award. **Clarify how construction/project implementation costs will be determined and reviewed.** In any design/build contract, the customer loses some design control. **Clarify design standards and the design approval process (including changes).**	
d. Hazardous Materials: The contractor is responsible to identify the presence of and include the cost of removal of any known and possible hazardous material for each ECM/WCM. The contractor and the customer will negotiate the responsibilities associated with the removal of the known and possible hazardous materials. In this context, responsibility refers to performance responsibility. **Clarify performance responsibilities associated with the removal of hazardous materials, both known and unknown.**	

[17] Additional guidance on utility rate estimations and weather normalization in an ESPC can be found at http://www.energy.gov/eere/femp/downloads/guidance-utility-rate-estimations-and-weather-normalization-espc.
[18] https://www.energy.gov/sites/default/files/2023-11/2023-doe-espc-idiq-rrp_matrix_gen4.docx

Responsibility/Description	Contractor-Proposed Approach
e. 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 (or water) savings determinations. The desired confidence will be reflected in the resources required for the M&V program, and the contractor must consider the M&V requirements before submitting the final proposal. **Clarify how project savings are being verified (e.g., equipment performance, operational factors, energy or water use) and the impact on M&V costs.**	
f. Energy (or Water)-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 in out-years based on avoided operations and maintenance (e.g., replacement costs) may involve certain risk to the customer (ordering agency) due to the timing and availability of such funds. Recurring savings generally result from reduced operations and maintenance (O&M) expenses. These O&M savings must be based on actual spending reductions. **Clarify sources of energy (and water) related cost savings and how they will be verified.**	
g. Delays: Both the contractor and the customer can cause delays. Failure to implement a viable project in a timely manner increases costs for the customer in the form of lost savings and can add various costs to the project (e.g., construction/project implementation interest, remobilization). **Clarify the schedule and how delays will be handled.**	
h. Major changes in facility: The 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(s).**	
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: Certain energy or 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 shall be contingent upon aggregate payments not exceeding aggregate savings. **Clearly specify weather data used and how weather corrections will be performed.**	
d. User participation: Many energy (or water) conservation measures (ECMs/WCMs) require user discretion (or even participation) to maintain or 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 the appropriate M&V method 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 design, installation, commissioning, and performance as well as all guaranteed energy and/or water savings. 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.**	

Responsibility/Description	Contractor-Proposed Approach
b. Operations: Performance of the day-to-day operations activities is negotiable and can impact performance. However, the contractor bears the ultimate risk of operations and all guaranteed energy and/or water savings 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 of maintenance and all guaranteed energy and/or water savings 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 of equipment repair, replacement, and all guaranteed energy and/or water savings 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. Clarify replacement responsibility when equipment life is shorter than the term of the contract.**	

[a] The FEMP Energy Savings Performance Contract (ESPC) risk, responsibility, and performance matrix is referenced in the US Department of Energy ESPC indefinite-delivery, indefinite-quantity contract and provided on the FEMP website. The USACE MATOC recommends using a similar matrix as well.

4 DETAILED M&V METHODS

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

The IPMVP defines four broad categories of 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 building or facility energy use and de-emphasize specific equipment performance. The primary difference in these approaches is where the measurement boundary is drawn, as shown in Figure 4-1. To determine savings, all energy used within the boundary, indicated by M (indicating meter) in Figure 4-1, 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.

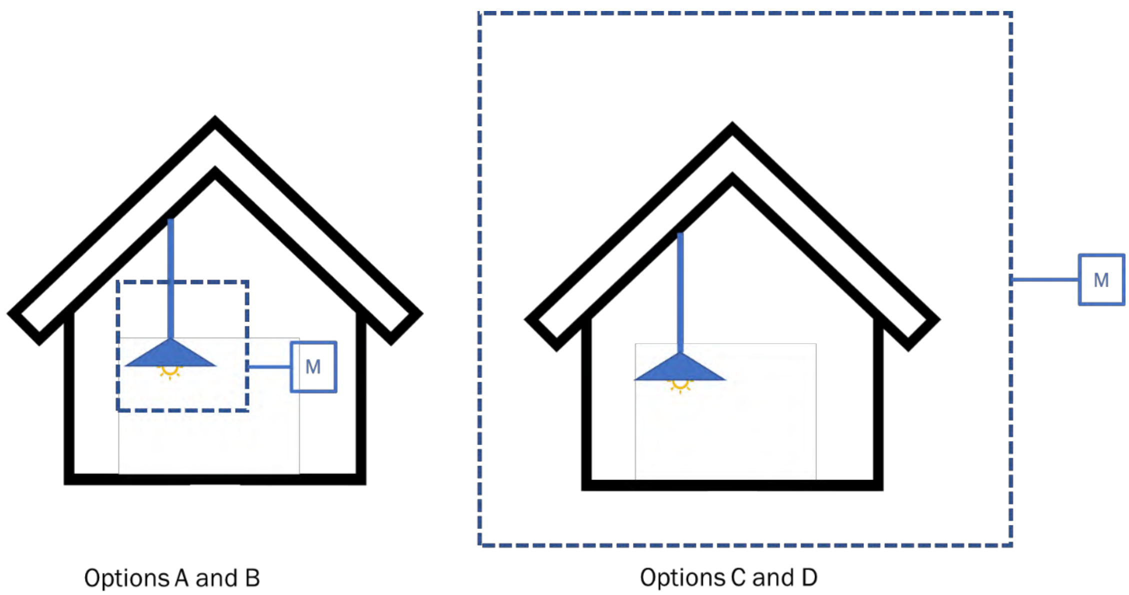

Figure 4-1. Retrofit-isolation M&V methods (options A and B) vs. whole-facility methods (options C and D).

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- or project-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 all savings are estimated values. The accuracy of these estimates, however, will improve with the number, duration 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 14-2023, Appendix B,[2] and in Uncertainty Assessment for IPMVP: International Performance Measurement and Verification Protocol®, EVO 10100 – 1:2018[19].

[19] Uncertainty Assessment for IPMVP: International Performance Measurement and Verification Protocol®, EVO 10100 – 1:2018, April 2018, Efficiency Valuation Organization.

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(s) 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 either measured or estimated based on facility use and occupant behavior to determine the baseline, and the same operating hours are used for annual performance measurement. 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 consumption (such as from utility billing data) at the whole facility or sub-facility level during the baseline and post-retrofit periods. This option requires an inventory of the equipment that is accounted for in the meter reading, as well as knowledge of equipment use patterns, building occupancy, and other factors affecting site or building energy consumption. Savings are determined from analysis of baseline and reporting-period energy data. Regression analysis is conducted to correlate energy consumption with independent variables such as weather and occupancy.	Replacement of a centralized heating plant (e.g., a campus-wide steam system) with decentralized heating (e.g., boilers in individual buildings). Using billing data during the baseline period (ideally going back several years), a regression model is developed of monthly consumption (of oil or natural gas, for example) with monthly heating degree days (HDDs). Following installation, actual (usually annual) performance period consumption is compared to what the model predicts *would have* been consumed in the absence of the retrofit, given the same number of HDDs. The difference represents the savings.

Measurement and Verification Options	Description	Examples
Option D—Calibrated Simulation	Computer simulation software is used to model energy performance of a whole facility (or sub-facility). Models must be calibrated with actual interval data (e.g., 15-minute, hourly, daily) 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 savings represents baseline energy consumption minus modeled post-retrofit energy consumption. To calibrate the model during the performance period, spot measurements of equipment are made to ensure that equipment performance conforms to the parameters used in the model.

4.2 OPTION A—RETROFIT ISOLATION WITH KEY PARAMETER(S) MEASUREMENT

M&V Option A involves a retrofit- or system-level 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 easily measured short- term, periodically, or continuously 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 meet performance requirements generate savings, and
- Verifies that the installed equipment/systems continue to meet performance requirements and yield 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, periodic, or continuous measurements, estimates, and engineering calculations. 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 a 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 performance period.

With Option A, savings are determined by measuring key parameters, such as capacity, efficiency, and/or operation of a system, before the retrofit and periodically during the performance period. Using estimates for certain parameters is sometimes warranted and is the easiest and least expensive method of determining savings. However, this can introduce significant uncertainty. Option A is often appropriate for certain types of measures 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 Uncertainty Assessment for IPMVP: International Performance Measurement and Verification Protocol®, EVO 10100 – 1:2018). While field testing of installed equipment is preferred, in instances where field testing is highly expensive relative to the expected savings, certified factory tests may be justified.

4.2.1.1 Measurements

Option A includes various methods and levels of accuracy in determining savings. 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 a key performance parameter that is often measured 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. 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. These estimated parameters, once established, are typically assumed to remain constant over the entire post-installation and performance period. 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 ECM.

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. The objective of Option B is to calculate savings in a manner similar to Option A, but Option B uses short-term, periodic or continuous measurement of *all relevant* parameters and/or *all* energy quantities needed to calculate energy use, during the performance period. This approach provides higher accuracy in the calculation of savings and increases the M&V cost.

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.
- Parameters effecting energy consumption (e.g., loads and operating hours) are variable.
- Operational data on the equipment are available through control systems or are easily measured.
- 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 measured or 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 performance 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 or measurement complexity increases.
- Depending on the ECM, 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 sub-meter data analysis 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. Use of Option C techniques may be appropriately applied for use in performance contracting projects, but there are several situations that can make Option C difficult to apply:

- A project in a multi-building facility often involves only a small subset of the buildings or equipment affecting the total facility energy use, 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, documenting actual read dates of meters to capture duration of data recorded. Data from these meters may be difficult to obtain and may be incomplete and/or of questionable accuracy.

- Even when accurate metered data are available for the affected 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 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 because of this, Option C models are sometimes not highly predictive of actual whole facility energy consumption.
- On its own, whole facility measurement does not provide the system level data needed to measure and potentially ensure optimal performance of specific ECMs.

Data analyzed from the meter(s) used in an Option C approach may include equipment outside the scope of the performance contracting project (e.g., plug loads such as copiers, microwaves, data servers), so the energy use of that equipment, including how those loads change over time, must be well understood to apply this option effectively. 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 criteria:

- Savings are predicted to be greater than about 10% to 15% of the overall consumption measured by the utility or submeter on a monthly basis.
- At least 12 (and preferably 24 or more) months of pre-installation data are available to calculate a baseline model to capture seasonal variation.
- Unless the model is very highly predictive, there is a risk that smaller percentage savings will be "lost in the noise" using monthly data.
- 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.
- Changes to the facility or its use that affect energy consumption are unlikely, or easily quantified, during the performance period.

Note that Option C may be applied to a single utility for a whole facility, with another M&V option applied to other utilities impacted by the proposed project or measure(s). Furthermore, given the changes in energy use that occur in most buildings with changes in mission, occupancy, and equipment loads, Option C may be more appropriate for use on a short-term basis (e.g., 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 (may be easiest where measurements are already being taken to validate or calibrate Option C regression models). An Option A approach could include equipment inspections, verification of trend data, and/or measurement of one or more key performance parameters as part of an overall operational verification approach.

4.4.1 Approach to Option C

With Option C, energy savings are determined using whole facility utility or other facility-level metered data. Savings are determined through analysis of these 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 alone 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. To account for any changes outside of the project that would be reflected in meter readings, this analysis will also include energy use of equipment beyond the scope of the performance contract.

4.4.2 Data Collection

Collecting, validating, and properly applying data are important elements of employing utility or metered data analysis. Option C techniques use three types of data: utility billing data or other metered data, data on independent variables (e.g., cooling degree days), and information on unrelated changes at the site (e.g., the addition of a new wing to the building). These data sources are discussed below.

4.4.2.1 Utility or Metered Data and Independent Variables

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 or more frequently (e.g., via on-line utility energy information systems). 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 consumption 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 consumption) for a given interval (e.g., 15-minutes) associated with the billing period. 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 information on the quantity of energy delivered can be used to determine historical consumption for resources such as fuel oil, although sub-metering 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 ECMs that affect overall site energy use, such as changes in square footage or loads. These are customarily referred to as static factors. Major changes in static factors, such as occupancy, operating hours, building or equipment loads, building or facility configuration or function, should be documented. Tracking site changes provides a means for accounting for changes in energy use beyond that associated with ECM installation. Adequately tracking the information needed to make these non-routine adjustments can be a challenging task and can increase the cost of performing M&V, however it is of major importance for the proper application of an Option C approach. Refer to the FEMP Supplement to these M&V Guidelines for more information on adjustments.

4.4.3 M&V Considerations[20]

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, often characterized in terms of heating or cooling degree days.

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 (see section 5.3.4.1 on model goodness of fit metrics).

- 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.

[20] See ASHRAE Guideline 14-2023, IPMVP Core Concepts (EVO 10000-1:2022) for additional information on utility billing analysis, and the Uncertainty Assessment for IPMVP (EVO 10100 – 1:2018).

4.5 OPTION D—CALIBRATED SIMULATION

Option D involves analysis of whole facilities or individual systems 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 calibrate 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.

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, and whole-facility approach is desired, yet Option C is deemed not suitable (e.g., because of an insufficiently predictive regression model).
- When whole-facility savings analysis is preferred, and savings levels are sufficient to warrant the cost of simulation.
- When energy savings values per individual measure are desired and interactive effects among ECMs need to be quantified but are too complex for retrofit isolation approaches
- When complex baseline adjustments are anticipated during the performance period
- When new construction projects are involved
- 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 such as radiant barriers or demand-response control algorithms that are important in comparing baseline and performance period scenarios depend on the capabilities of the simulation software; or
- 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, should be performed by an accomplished building simulation specialist and require customer expertise to review and validate the model inputs and outputs. 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

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®: Core Concepts, EVO 10000 – 1:2022.[21] 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 is 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 accurate 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 sub-system metering must be included in the project M&V activities for the baseline and performance periods. The specific sub-systems selected for monitoring are in most cases the installed ECMs and related systems. For ECMs such as windows or insulation that cannot be readily monitored, the affected HVAC system should be sub-metered. 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 (e.g., natural gas) consumption. Additional data in hourly and 15-minute formats may be required.
- Architectural, mechanical, and electrical drawings. Current as-built drawings are preferred, documenting any changes since existing as-builts were completed.

[21] International Performance Measurement and Verification Protocol (IPMVP®): Core Concepts (EVO 10000 – 1:2022).

- 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, occupancy 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 (e.g., solar heat gain coefficient and U-value) 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. Condition and functionality should also be determined (e.g., whether outdoor air dampers are operational or failed open/closed)
- Short-term monitoring. The building energy management control system (EMCS) or data-logging equipment is set up to record system data over time. Typically, energy- using systems and equipment involved in an ECM are monitored. These data may be required if particular sub-systems (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.[22] 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 detailed site data incorporated, the more accurate the savings calculations will be, 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, 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 those requirements are met.

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.

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

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, and so on. 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. 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, estimated 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 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, typical weather data (e.g., TMY data) should be used. In any case, both the baseline and performance period models must be run with the same weather data. The weather data to be used are specified in the project-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 calculated by taking the difference in energy or demand use between two consecutive runs. The savings determined for the individual ECMs should total the savings 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 from 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 time-variable pricing rates 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.[23] Resources for building energy modelers, including a link to a list of available energy simulation programs, is maintained by the US Department of Energy (DOE).[24] These building simulation programs require extensive input data to accurately model the energy use of a building. User interfaces have 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:[25]

- Commercially available, supported, and documented.
- Able to adequately model the project site and ECMs.
- Able to be calibrated to an acceptable level of accuracy.
- Able to use actual weather data in hourly format.

4.5.3 Model Calibration[26]

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

[23] eQUEST is available through http://doe2.com/equest/ and EnergyPlus is available through https://energyplus.net/.
[24] See https://www.energy.gov/eere/buildings/building-energy-modeling.
[25] 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 14-2023.
[26] See ASHRAE Guideline 14-2023 and IPMVP Core Concepts (EVO 10000-1.2022) for additional information on simulation modeling and validation techniques.

typically an iterative process of adjusting model inputs and re-comparing the results to measured data. A model is considered in calibration when the statistical indices demonstrating calibration have been met. Industry standard guidelines are included in Table 4-2. Expected calibration requirements should be specified in the project M&V plan. These requirements may 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 14-2023, Section 5.3.3.3.10.
[b]Lower values indicate better calibration.
Abbreviations: 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. Calibration procedures apply to all sources of savings (demand, electricity, natural gas, etc.) and should focus on the primary sources. 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. 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. Model calibration strategies are discussed below.

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. Examples of resources for real-time weather data are:

- National Oceanic and Atmospheric Administration – the National Center for Environmental Information (NOAA NCEI)[27] maintains a website that provides historical weather data. The data can be accessed by station name, zip code, city, county, or state. These data include quality controlled daily, monthly, seasonal, and yearly measurements of temperature, precipitation, wind, and degree days as well as radar data and 30-year Climate Normals.[28]
- National Renewable Energy Laboratory – the National Solar Radiation Database (NREL NSRDB)[29] is a serially complete collection of hourly and half-hourly values of meteorological data and the three most common measurements of solar radiation: global horizontal, direct normal and diffuse horizontal irradiance. NSRDB data are compatible with many system performance and economic models.

Other sources of these data are available and can be used, however, citations should always be referenced. Because using actual weather data can be time -consuming, it is sometimes appropriate to modify average weather to more closely match the actual weather.[30] Typical meteorological year (TMY) source data are available from the NSRDB[29], and many building simulation programs can convert the data into the format needed for their use. EnergyPlus[31] and eQUEST[32] are examples of simulation programs that also provide formatted weather data for locations in US and around the world.

The time period and frequency of the weather data need to align with the utility data periods, which can require data manipulation. The M&V plan must specify which weather data sources will be used, including the source of the data, the range of years included in the TMY dataset, and the physical location of the weather station.

4.5.3.2 Statistical Indices

For 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)].[33] 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.

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

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[27] Climate.gov – Past Weather by Zip Code, https://www.climate.gov/maps-data/dataset/past-weather-zip-code-data-table
[28] U.S. Climate Normals, https://www.ncei.noaa.gov/products/land-based-station/us-climate-normals
[29] National Solar Radiation Database, https://nsrdb.nrel.gov/
[30] https://www.osti.gov/servlets/purl/453496
[31] https://energyplus.net/
[32] eQUEST, https://doe2.com/index_Wth.html
[33] See ASHRAE Guideline 14-2023 and Section 4.2.2 for additional information.

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 - indicates how well the energy consumption is predicted by the model as compared to the measured data. Positive values indicate that the model over predicts actual values; negative values indicate that the model under predicts 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) - 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.

MBE 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.

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

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

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

$$C_v(RMSE_{Period}) = \frac{RMSE_{Period}}{A_{Period}} \; x \; 100$$

The primary differences in applying these indices to the various data sets (monthly, hourly, sub-metered) 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 specified in the project M&V plan.

4.5.3.3 Sub-system 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 consumption (kilowatt-hours, therms, or Btus) predicted by the model is compared against measured hourly energy consumption for the monitored building sub-systems to determine whether the model accurately predicts sub-system level consumption.

Most simulation programs, including eQUEST, output sub-system usage values in 1-hour intervals at a minimum. 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 sub-metered data, the interval is one hour, and the period can be defined by the user.

4.5.3.4 Whole Facility Level Calibration with Monthly Data

Comparing energy consumption 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 one month, and the period is one year.

4.5.3.5 Whole Facility Level Calibration with Hourly Data

When hourly data are applied, the interval is one 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.[34]

4.5.4 M&V Considerations

Many issues must be considered and addressed in developing a project 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 sub-system 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 facilitates sub-system 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 control sequences. 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 EMCS trend data. Sometimes, EMCS systems can be used to determine actual operating scenarios. However, the capability for data storage in many systems may be limited.

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[34] 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.

- 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 and date range 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. Otherwise, Option A or B retrofit isolation methods may be preferred. Regardless of how savings are calculated each year, the ongoing performance of the measures needs to be verified periodically.

5 SELECTING AN M&V APPROACH

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

M&V activities include site surveys, metering or measurement of energy and independent variables, engineering calculations, and reporting. These activities may differ between the baseline period and performance period. 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.

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

- Project and individual ECM costs and expected savings
- Complexity of the ECMs
- Number of interrelated ECMs at a single facility
- Ease or cost of measurements
- Uncertainty or risk of savings being achieved
- Other uses for M&V data and systems

This section discusses these issues, rules of thumb to use when selecting an M&V approach, and a method for evaluating 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 M&V plan should be prepared with consideration of M&V requirements, ECM value and complexity, interrelated ECMs, and performance risk. These key factors, described further below, should be considered when developing the M&V plan for each ECM and project.

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

The value of a given ECM may depend on a number of factors, including its cost and savings (on its own and compared to other ECMs in the project), energy rates, term of the contract, allocation of risk and responsibility (e.g., complexity of O&M/R&R, which party will perform specific O&M/R&R tasks, and how O&M/R&R will be monitored and reported), and magnitude of overall savings. The M&V effort should be scaled 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.

5.1.2 Complexity of ECM or System

More complex ECMs and projects may warrant more complex (and thus more expensive) M&V. In general, the complexity of isolating ECM performance 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. As another example, power output of a photovoltaic system is straightforward to meter, however M&V calculations become more complex when a portion of the power offsets building electrical consumption, and another portion charges a battery for later use.

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 building or 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 building or site. Examples include interactive effects between lighting and heating or cooling 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 energy or cost savings. An ECM with which the facility staff is familiar may require less M&V rigor than ECMs that are less well known. Similarly, advanced technologies may warrant additional attention.

Savings risk can be based on the estimated project value, technical uncertainty, and customer experience. As a starting point, consider the project's potential to perform and estimated savings uncertainty. A simplified illustration is shown in Table 5-1.

Table 5-1. Hypothetical 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

For the "large custom" measure, alternative M&V approaches could be evaluated based on a comparison of estimated savings risk with the expected cost for each M&V option.

5.1.4.1 Other Uses for M&V Data and Systems

The array of instrumentation installed, and measurements collected for M&V can often be used for other purposes, including commissioning, system optimization, and periodic re-commissioning 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, e.g., for allocating costs among different tenants, planning future projects, or allocating research.

Monitoring-based commissioning (MBCx) is a process of analyzing energy system problems and implementing and verifying improvements on an ongoing basis. MBCx can be used to enhance M&V for certain ECMs or projects, as well as automatically detect and diagnose causes of equipment or system performance issues. This can also provide for optimized O&M of installed equipment and systems, as well as performance and energy consumption, which is critical to sustaining ECM and project performance and energy savings over the performance period.

5.2 COST AND RIGOR

In general, the more rigorous the M&V, the more expensive it will be. The factors that typically affect M&V accuracy and costs (some are interrelated) include:

- Level of detail and effort associated with verifying baselines 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 activities 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 managing costs while maintaining technical rigor:

- Use extensive metering in the baseline period and stipulate values over which the contractor has no control.
- Verify key performance indicators 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.

- If needed, engage a third-party M&V expert to assist in development of the M&V plan and review of M&V reports to ensure key customer interests are protected, risks are managed, and costs are minimized. If third party M&V support is needed, this should be addressed during project development.

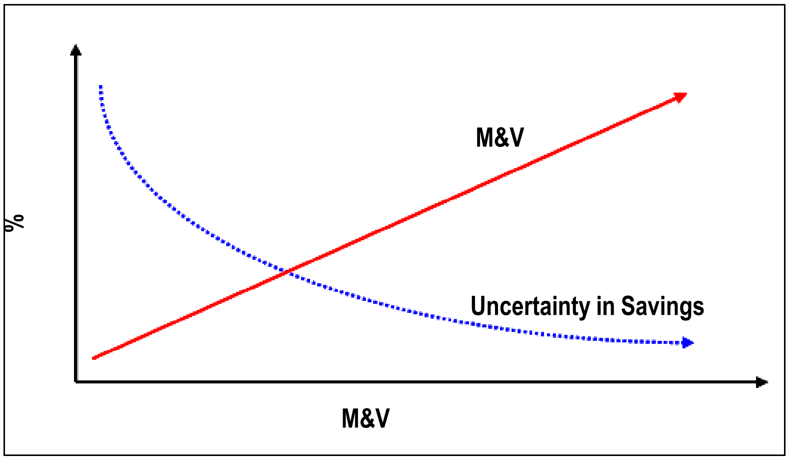

Figure 5-1. The Law of Diminishing Returns for M&V.

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 (based on the DOE ESPC IDIQ program history) put overall annual M&V costs at 1.5% to 3% of typical annual project guaranteed cost savings.[35]

More complex ECMs may entail greater M&V costs, rigor, and accuracy but may be balanced by other ECMs that require less effort.

5.3 UNCERTAINTY

Any statement of measured savings includes some degree of uncertainty. A goal for each project is to balance the uncertainty in 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 degree of uncertainty in *estimated* savings is not required for federal projects, but the underlying uncertainty in individual ECMs' savings is used by contractors (particularly ESCOs conducting ESPCs) to determine the savings *guarantee* for the project.

Including uncertainty in calculating savings values provides a more realistic picture of savings. Uncertainty is typically proportional to the complexity of the ECM.

[35] For ESPCs awarded under the DOE ESPC IDIQ contract, annual reports summarize the realization rate of energy and cost savings, including the M&V costs. https://www.energy.gov/femp/articles/reported-energy-and-cost-savings-espc-program

Uncertainty at the project level can be broken down into four general types: instrumentation and data collection ("measurement" for the purposes of equation 5-1 below), sampling, estimation, and modeling. For any given project, the project error is calculated from these four uncertainties. Frequently projects do not contain all four components; however, in a hypothetical project with all four, assuming no correlation between errors, the total project uncertainty (the standard error, in statistical terms) would be calculated by taking the square root of the sum of the squares of the individual standard errors of the components:

Equation 5-1: Total Project Estimated Savings Uncertainty

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

The following sections discuss the sources of these errors and the ways that the errors can be minimized.[36]

5.3.1 Instrumentation and Data Collection

Instrumentation equipment inaccuracies and missing or erroneous data collection leads to measurement uncertainty. 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. Improper data management can also introduce errors through flawed, omitted, adjusted, or lost data.

For an M&V plan to be successful, 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 instrumentation and data collection can contribute to uncertainty in calculated savings.

For example, in a chiller project it is often necessary to measure efficiency in kilowatts (kW) per ton (kW/ton). The capacity in tons is determined by measuring the flow rate and temperature difference 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 difference for various levels of temperature sensor accuracy (given a ± 5% error in flow measurement and a ± 2% error in in power measurement) from 3.0°F to 0.10°F (top to bottom).

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

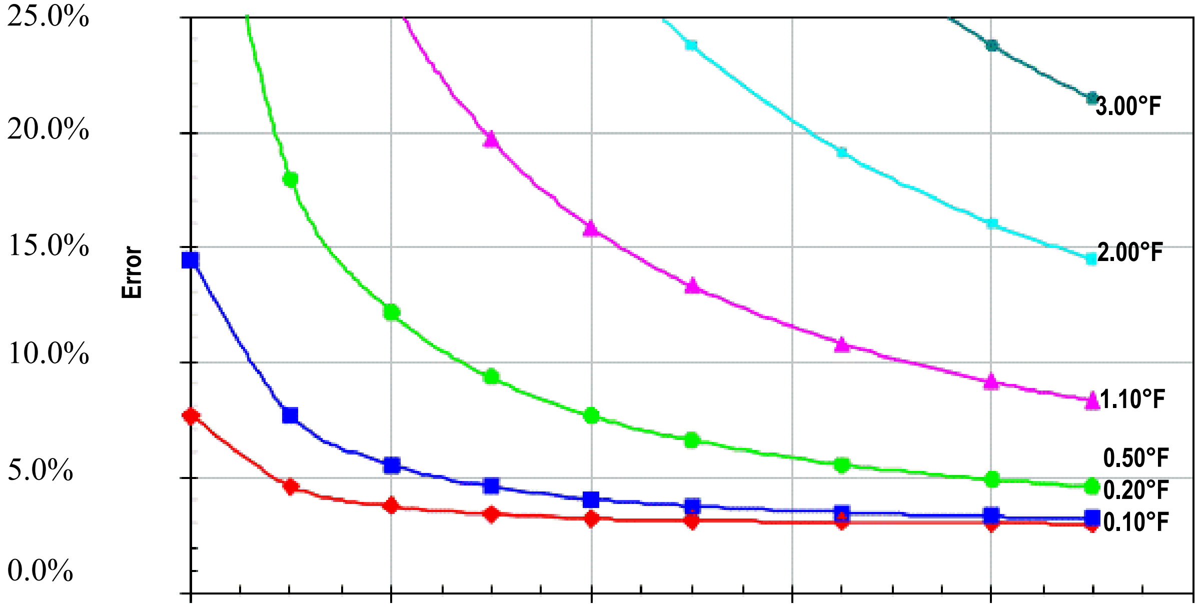

Figure 5-2. Example Influence of Sensor Accuracy on Calculations.[37]

Uncertainty of Calculated Kilowatts per Ton vs. Differential Temperature at Various Temperature Sensor Accuracies, assuming Flow Measurement Error = ± 5% Power Measurement Error = ± 2%

The following are tips for reducing measurement errors:

- Determine and prescribe the needed accuracy for measurement equipment.
- Ensure that the instrumentation has been recently calibrated or calibrated at manufacturers recommended intervals.
- 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 Uncertainty Assessment[38] and in DOE FEMP's Supplement to M&V Guidelines.

The following are tips for reducing sampling errors:

[37] Analysis provided by Scott Judson, formerly Director of Performance Engineering, NORESCO.
[38] International Performance Measurement and Verification Protocol: Uncertainty Assessment for IPMVP, EVO-10100-1.2019, Efficiency Valuation Organization.

- 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 at least meet an 80% confidence and 20% precision.[39]
- 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 considerable variation. This will increase the initial sample size but reduce the risk of under-sampling.

Though sampling is often applied to lighting or water retrofit measures, it may be appropriate to apply this approach to instances where there is a large quantity of equipment with similar performance or operating characteristics.

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.

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[40] 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.

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. Using measured or metered data of key energy using systems as

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[39] See latest version of FEMP M&V Supplement for table listing sample sizes for confidence and precision.
[40] Typical meteorological year weather data are available from the National Renewable Energy Laboratory (https://nsrdb.nrel.gov/data-sets/tmy).

inputs to the model, calibrating the model to interval, hourly or daily data can all contribute to managing and decreasing uncertainty and modeling errors. Goodness of fit metrics are typically used to ensure the model developed for either Option B or C is adequate. These metrics provide an assessment the model's ability to capture variation in the data while ensuring the independent variables are relevant along with an assessment of the underlying error in the model.

5.3.4.1 Goodness of Fit Metrics

Goodness of fitness metrics ensure adequate model development and are typically used for either Option B or C. These metrics provide an assessment the model's ability to capture variation in the data while ensuring the independent variables are relevant along with an assessment of the underlying error in the model. Several of these metrics are described in greater detail below.

<u>Coefficient of Determination (R2).</u> Coefficient of Determination, R2, measures the extent to which variations in the dependent variable y can be explained by the regression model. R2 ranges between 0 and 1, a value of 0 indicating that none of the variations can be explained by the model and that the model provides no guidance in understanding the variations in y using the selected independent variables; a value of 1 indicates the model explains 100% of the variations in y. Generally, the greater the R2, the better the model describes the relationship of the independent variables and the dependent variable. For example, IPMVP states that a minimum acceptable R2 value is 0.75.

<u>Root Mean Squared Error (Standard Error of the Estimate)</u>. Root mean squared error (RMSE), or Standard error of the estimate (SE) is an indicator of the scatter, or random variability, in the data, and hence is an average of how much an actual y-value differs from the predicted y-value. It is the standard deviation of errors of prediction about the regression line.

<u>Coefficient of Variation of the Root Mean Squared Error CV(RMSE)</u>. CV(RMSE) is the RMSE normalized by the average y-value. Normalizing the RMSE makes this a non-dimensional that describes how well the model fits the data. It is not affected by the degree of dependence between the independent and dependent variables, making it more informative than R-squared for situations where the dependence is relatively low.

<u>Bias.</u> Net determination bias is the percentage error in energy use predicted by the model compared to actual energy use. The sum of the differences between actual and predicted energy use should be zero. If the net determination bias = 0, then there is no bias. ASHRAE Guideline 14-2002 accepts an energy model if the net determination bias error is less than 0.005%. Often bias may be minor but will affect savings estimates. If the savings are large relative to the bias, bias may not be important, but in many cases, bias could be influential.

<u>t-Statistic</u>. The t-statistic is a measure of the significance for each coefficient (βi) and the related independent variable's contribution to the overall model. The larger the t-statistic, the more significant the coefficient is to estimate the dependent variable. The coefficient's t-statistic is compared with the critical t-statistic associated with the required confidence level and degrees of freedom. For a 95% confidence level and a large number for degrees of freedom (associated with a lot of data), the comparison t-statistic is 1.96. IPMVP specifies that the t-Statistic to be greater than 2.0 for the independent variable to be significant.

6 GUIDANCE FOR SPECIFIC ECMs

This section provides general M&V guidelines for standard ECMs typically implemented under performance contracts and other energy conservation projects.[41] It includes procedures and elements for quantifying the savings resulting from energy efficiency equipment, water conservation, and renewable energy projects. The emphasis is on key elements that should be considered when performing M&V on specific ECMs. The material presented in this section is intentionally simplified to provide an idea of the general approach to evaluate most common ECMs. Therefore, these samples are not to be considered as actual M&V plans. In reality, a detailed M&V plan must be tailored to a specific ECM and take into account project-specific variations as outlined in ESPC M&V Plan Outline (Appendix C). The guidance in this section is a broad approach for general ECM technology categories, and the outlines provided do not consider ECM size, cost and savings. As such, sample sizes presented are provided as examples for consideration when developing the project-specific M&V plan; these may be customized to meet required rigor for individual ECMs or project needs. These M&V plan guidelines assume that the ECMs are independent and do not have interactive effects with other ECMs. Comprehensive and net impact should be considered when multiple different ECMs in a single building or project are being implemented and their effect on the choice of M&V technique should be considered. In such cases, Option C or D may be more appropriate for those projects with highly interactive ECMs, which is not specifically addressed in this section.

Although there could be other approaches, the examples provided below may be used as a sample. Examples of detailed M&V plan templates for select ECMs can be found in the FEMP Supplement to these M&V Guidelines.

ECMs described in this section are organized by DOE ESPC IDIQ Technology Categories, as shown in the table below, with proposed M&V option.

Table 6-1. Summary of Included ECMs/WCMs and Proposed M&V Option by DOE Technology Category

Technology Category	Energy/Water Conservation Measure	M&V Option
Boiler Plant Improvements	ECM: Distributed High Efficiency Boilers	A
Chiller Plant Improvements	ECM: Chilled Water Equipment Replacement	B
	ECM: Heat Recovery Chiller	B
Building Automation Systems (BAS) / Energy (Utility) Management Control Systems (EMCS)	ECM: Energy Management Control System	B
	ECM: Variable Air Volume Conversion	B

[41] The ESPC authority requires that a measure meet certain criteria to qualify as an "energy conservation measure" or a "water conservation measure." *See* 42 U.S.C. §§ 8259(4), 8287c(4); 10 C.F.R. § 436.31. Although section 6 provides an overview of measures commonly implemented in performance-based contracts, an agency must ensure that implementation of any measure is consistent with the ESPC and UESC authorities.

Technology Category	Energy/Water Conservation Measure	M&V Option
Heating, Ventilating, And Air Conditioning (HVAC) Improvements	ECM: Heat Recovery Systems	B
	ECM: Replace Self-Contained Air Conditioning with Chilled Water	A
	ECM: Air Source Heat Pumps	B
Lighting Improvements	ECM: Lighting	A
	ECM: Lighting Controls	A
Building Envelope Modifications	ECM: Building Envelope Improvements	A
Chilled Water, Hot Water, And Steam Distribution Systems	ECM: Steam Trap Replacement	A
Electric Motors and Drives	ECM: Premium Efficiency Motors	A
	ECM: Variable Speed Pumping	A
Refrigeration	ECM: High-Efficiency Refrigeration Equipment	A
Distributed Generation	ECM: Combined Heat and Power	B
Renewable Energy Systems	ECM: Renewable Generation	B
	ECM: Renewable Energy Offset	B
Energy/Utility Distribution Systems	ECM: Electrical Transformer Replacement	A
Water And Wastewater Conservation Systems	ECM: Plumbing and Indoor Water Equipment	A
	ECM: Water Metering	B
	ECM: Process Water Equipment	B
	ECM: Irrigation Systems	B
	ECM: Alternative Water Systems	B
Electrical Peak Shaving/Load Shifting	ECM: Battery Energy Storage Systems	B
	ECM: Thermal Energy Storage	B
Energy Cost Reduction Through Rate Adjustments	ECM: Dispatchable Load Management	C
Energy Related Process Improvements	ECM: Air Compressor and Vacuum Pump Improvements	B
	ECM: Grid-Interactive Efficient Building (GEB)	B
Commissioning	ECM: Retro-commissioning/Recommissioning	A
	ECM: Monitoring-Based Commissioning	B

6.1 BOILER PLANT IMPROVEMENTS

Measures under this technology category include improvements related to boiler plant systems such as, but not limited to boiler control, including new controls and retrofits to existing controls, replacement of existing boilers with high efficiency boilers, and boiler decentralization.

6.1.1 ECM: DISTRIBUTED HIGH EFFICIENCY BOILERS

This measure involves switching from a central steam or hot water plant to distributed non-condensing high efficiency boilers (note that condensing boilers require a different approach). Savings are the result of improved boiler efficiency and may include reduced distribution losses.

6.1.1.1 M&V Plan Description

Option A is recommended to validate ECM performance during the performance period through measurement of key parameter(s). Boiler loads (annual output in MMBtu) are established using boiler logs from the baseline period and/or other data to capture the demand associated with demand for hot water or steam. This could be done through trending relevant data through EMCS and metering of gas or fuel consumption. The fuel savings shall be calculated based on the efficiency of the replacement boilers and the baseline equipment. Additional water savings may also result based on the ECM.

6.1.1.2 M&V Option Selection Rationale

Savings vary based on many parameters including existing equipment efficiency, heating load, part-load performance, and run hours. Due to the multiple interactions between HVAC equipment and building load it is recommended to develop an energy analysis model to evaluate the savings from the installation of higher efficiency boiler systems.

During ECM development, the model will serve to establish the baseline and predict the post-retrofit energy consumption based on the ECM's effects within the model. The energy model will be calibrated with utility data and spot measurements in order to develop an acceptable baseline representation and ultimately predict energy savings. The recorded key parameter data will be used as inputs to the model. Performance parameters (Table 6-1.1) include the performance of a combustion efficiency test on all the boilers at various loads during baseline development, post-installation, and the performance period. Operational hours (runtimes) at various loads will be measured during the baseline and will be assumed to remain constant for the post implementation period and the rest of the performance period.

Table 6-1.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Boiler Combustion Efficiency			
Performance	Baseline	All boilers	Spot check at various loads
Performance	Post-Installation	All boilers	Spot check at various loads
Performance	Performance	All boilers	Spot check at various loads
Operating Hours			
Operational	Baseline	All boilers	Operating hours at each load factor
Operational	Post-Installation	All boilers	Stipulated – same as baseline period
Operational	Performance	All boilers	Stipulated – same as baseline period

The associated water savings may also 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 post-installation period through EMCS and or metering the water usage.

6.1.1.3 M&V Performance Assurance Activities

- Verify installation of distributed high efficiency boilers.
- Verify boilers are operating as intended via combustion efficiency tests at various loads
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Customer witnessing of M&V activities.

6.2 CHILLER PLANT IMPROVEMENTS

Measures under this technology category include any improvements related to chiller plant systems such as, but not limited to chiller retrofits or replacements, and chiller plant pumping, piping, and controls retrofits and replacements.

6.2.1 ECM: CHILLED WATER EQUIPMENT REPLACEMENT

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

6.2.1.1 M&V Plan Description

Option B is recommended to validate ECM performance during the performance period through continuous measurement of key parameters. A calibrated model is recommended to estimate energy savings associated with improved chiller plant efficiency.

6.2.1.2 M&V Option Selection Rationale

The overall savings associated with this measure can be quantified by measuring the efficiency of the installed equipment and runtime. The efficiency and runtime will be used to determine savings using a calibrated energy analysis model. The baseline model is calibrated to utility bills or short-term metered data.

Performance parameters (Table 6-2.1) include the spot measurement of chiller plant efficiency. For electric chillers this is kilowatts per ton. Plant efficiency should be recorded during the baseline development, post-installation, 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. During ECM development, the model will serve to establish the baseline and predict the post-retrofit energy consumption based on the effect of the ECM within the model. The energy model will be calibrated with past utility data and spot measurements in order to develop an acceptable baseline representation. The recorded data will be used as inputs to the model.

Table 6-2.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Overall Chiller 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 Energy Consumption			
Operational	Baseline	All equipment	Submetering
Operational	Post-Installation	All equipment	Submetering
Operational	Performance	Trending of all equipment	EMCS

6.2.1.3 M&V Performance Assurance Activities

- Verify installation of new plant equipment and efficiency.
- Perform efficiency spot checks on equipment to ensure efficiency has improved.
- Perform long-term logging on plant runtime 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.
- Customer witnessing of M&V activities.

6.2.2 ECM: HEAT RECOVERY CHILLER

This measure involves installing heat recovery chillers (HRC) capable of producing chilled water and heating water at the same time. HRC can provide significant energy savings when there is a simultaneous need for chilled water and heating water. HRC can also save a significant amount of water compared to a chiller and cooling tower. Energy savings are the result of the higher efficiency of HRC, and water savings are the result of the reduction of cooling tower water use. The performance of HRC varies based on the required chilled water and heating water temperature.

6.2.2.1 M&V Plan Description

Option B is recommended to validate ECM performance during the performance period through metering of all parameters. Simultaneous cooling water and heating water loads shall be established using cooling water and heating water loads from the baseline period and/or other data (EMCS, metering, etc.). Energy savings shall be calculated based on the efficiency of the existing baseline equipment and the proposed new HRC. If the baseline equipment includes a chiller and cooling tower, water savings shall be calculated based on the baseline water use of the cooling tower.

6.2.2.2 M&V Option Selection Rationale

Performance parameters (Table 6-2.2) include the performance of the baseline chiller and water heating equipment during baseline development. The efficiency of the HRC shall be established during post-installation activities and measured continuously during the performance period.

Table 6-2.2. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Equipment Efficiency			
Performance	Baseline	All affected cooling and heating equipment	Short-term metering
Performance	Post-Installation	All installed HRC	Short-term metering
Performance	Performance	All installed HRC	Continuous
Operating Hours			
Operational	Baseline	All affected cooling and heating equipment	Operating hours at each load factor
Operational	Post-Installation	All installed HRC	Stipulated – same as baseline period
Operational	Performance	All installed HRC	Stipulated – same as baseline period

6.2.2.3 M&V Performance Assurance Activities

- Verify installation of HRC.
- Verify the HRC is operating as intended and efficiency maintained through monitoring.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Customer witnessing of M&V activities.

6.3 BUILDING AUTOMATION SYSTEMS (BAS) / ENERGY MANAGEMENT CONTROL SYSTEMS (EMCS)

Measures under this technology category include any improvements related to building automation systems or energy management control systems such as, but not limited to the installation of a new BAS / EMCS, upgrading or replacement of existing BAS/EMCS, or HVAC upgrades from pneumatics to direct digital control.

6.3.1 ECM: ENERGY MANAGEMENT CONTROL SYSTEM

This measure involves installing controls that allow for optimized control of HVAC equipment and other energy-consuming devices for effective and efficient operation.

6.3.1.1 M&V Plan Description

Option B is recommended to validate ECM performance during the performance period through continuous measurement of key parameters. Under this strategy, ongoing performance measurements (i.e., air handling unit (AHU) runtime, reset schedules, etc.) are collected through the Energy Management Control System (EMCS). A review of EMCS trend logs on an annual basis will be used to verify ECM savings during the performance period.

6.3.1.2 M&V Option Selection Rationale

Energy 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 to evaluate the savings from the installation of a control system to optimize the performance and runtime of the HVAC equipment.

During ECM development, the model will serve to establish the baseline and predict the post-retrofit energy consumption based on the ECM's effects within the model. The energy model will be calibrated with past utility data and spot measurements in order to develop an acceptable baseline representation and ultimately predict energy savings. The recorded key parameter data will be used as inputs to the model. Performance parameters (Table 6-3) include unit power. This would be obtained for the baseline development by measuring unit kilowatts; however, it may be necessary to determine the difference in flow and temperature to determine newly installed energy consumption. It is also recommended to monitor HVAC equipment to verify proper operation through short-term data logging through EMCS as this is an excellent source of data collection and thus will be used to implement M&V for this ECM.

Performance parameters of identified HVAC equipment (Table 6-3) 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. 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. 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 (temperature set points, setbacks, reset schedules, runtimes, etc.) will be determined during the short-term data logging conducted for a representative number of the existing equipment to verify the operating schedules.

Post-installation, operation of EMCS will be verified during the commissioning process to ensure functionality.

Table 6-3.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
HVAC Equipment Power (kW)			
Performance	Baseline	20% (focus on larger HVAC equipment with controls)	Short-term measurements
Performance	Post-Installation	20% (focus on larger HVAC equipment with controls)	Short-term measurements

Performance	Performance	Review trend logs	From EMCS
HVAC Equipment Runtime (hours)			
Operational	Baseline	20% (focus on larger HVAC equipment with controls)	Short-term measurements
Operational	Post-Installation	20% (focus on larger HVAC equipment with controls)	Short-term measurements
Operational	Performance	Review trend logs	From EMCS
Temperature Set points, Setbacks (°F)			
Operational	Baseline	20% (focus on similar spaces with majority of building space)	Short-term measurements
Operational	Post-Installation	20% (focus on similar spaces with majority of building space)	Short-term measurements
Operational	Performance	Review trend logs	From EMCS
Temperature Reset Schedules (°F)			
Operational	Baseline	20% (focus on larger HVAC equipment with controls)	Short-term measurements
Operational	Post-Installation	20% (focus on larger HVAC equipment with controls)	Short-term measurements
Operational	Performance	Review trend logs	From EMCS

6.3.1.3 M&V Performance Assurance Activities

- Verify installation of control hardware and operational parameters remain unchanged.
- Verify that spaces are achieving desired heating and cooling set points.
- Perform post-installation short-term measurements and use the EMCS trending data during the performance period to demonstrate energy savings.
- Verify that the system remains set up and is recording relevant trend logs.
- 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.
- Customer witnessing of M&V activities.

6.4 HEATING, VENTILATING, AND AIR CONDITIONING (HVAC) IMPROVEMENTS

Measures included in this technology category are related to heating, ventilating, and air conditioning (HVAC) improvements such as but not limited to - packaged air conditioning unit replacements and/or repairs, HVAC damper and controller repair or replacement, window air conditioning replacement with high efficiency units, cooling tower retrofits or replacements, economizer installation, fans and pump replacement or impeller trimming, and variable air volume retrofit. This category does not include measures related to boilers, chillers, and BAS/EMCS that are part of other technology categories.

6.4.1 ECM: VARIABLE AIR VOLUME CONVERSION

This measure involves replacing constant volume air handling units (AHU) with variable air volume (VAV) air handlers with VAV terminal units. 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.

6.4.1.1 M&V Plan Description

Option B is recommended to validate ECM performance during the post-installation and performance periods through continuous measurement of key parameters. Under this strategy, post-installation and ongoing performance is evaluated by collecting key data points (i.e., AHU runtime, motor speeds, VAV positions) through the EMCS or sub-metering. A review of EMCS trend logs on an annual basis will be used to verify ECM savings during the performance period.

6.4.1.2 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 calibrated.

The energy model will be calibrated with past utility data and spot measurements in order to develop an acceptable baseline representation. The model can be used to predict savings by comparing the energy baseline with post-retrofit energy consumption based on the effects of the ECM within the model. The recorded data will be used as inputs to the model to assess the impact of the ECM.

During the performance period, performance is assured through review of trend logs to ensure operating conditions are being maintained and inspection of the equipment (see Table 6-4.1).

Table 6-4.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Fan Power (kW; runtime based on measurements)			
Performance/Operational	Baseline	20% (focus on larger AHUs)	Short-term metering
Performance/Operational	Post-Installation	Review trend logs	From EMCS
Performance/Operational	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

6.4.1.3 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.
- Verify adherence to control sequences and strategies through EMCS.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Customer witnessing of M&V activities.

6.4.2 ECM: HEAT RECOVERY SYSTEMS

This measure involves the installation of heat recovery units (HRUs) on existing AHUs to reduce HVAC heating and cooling energy. These HRUs reuse normally wasted heat by enthalpy recovery equipment and transferring that to the incoming supply air.

6.4.2.1 M&V Plan Description

Option B is recommended to validate ECM performance during the performance period through short-term measurement of key parameters. Under this strategy, ongoing performance measurements (i.e., fan speed, supply, return, exhaust air temperatures.) are collected through the EMCS or sub-metering. A review of EMCS trend logs on an annual basis will be used to verify ECM savings during the performance period.

6.4.2.2 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 to analyze the savings from installation of heat recovery equipment.

Performance parameters (Table 6-4.2) include fan flow, supply and exhaust air temperatures across the heat exchanger to calculate the enthalpy gain by the supply air. 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 (runtimes) will be verified by measuring AHU runtimes. This short- term data logging will be conducted for a representative number of the existing AHUs to verify runtimes during the baseline development and post-installation. 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 6-4.2. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Supply Air Temperature, Pre- and Post-Heat Recovery			
Performance	Baseline	50% of HRUs	Short-term measurements
Performance	Post-Installation	50% of HRUs	Short-term measurements
Performance	Performance	20% of HRUs (rotating)	Short-term measurements
Exhaust Air Temperature, Pre- and Post-Heat Recovery			
Performance	Baseline	50% of HRUs	Short-term measurements
Performance	Post-Installation	50% of HRUs	Short-term measurements
Performance	Performance	20% of HRUs (rotating)	Short-term measurements
Supply and Exhaust Air Flow			
Performance	Baseline	50% of HRUs	Short-term measurements
Performance	Post-Installation	50% of HRUs	Short-term measurements
Performance	Performance	20% of HRUs (rotating)	Short-term measurements
Equipment Runtime (hours)			
Operational	Baseline	50% of HRUs	Short-term measurements
Operational	Post-Installation	Baseline	None
Operational	Performance	Baseline	None

6.4.2.3 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.
- Customer witnessing of M&V activities.

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

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 or packaged air conditioning (AC). Self-contained AC is not an efficient approach due to poor operating efficiencies and lack of system control or monitoring capabilities.

6.4.3.1 M&V Plan Description

Option A is recommended to validate ECM performance during the performance period through short-term measurement of selected key parameters. A calibrated model is recommended to quantify the energy savings associated with replacement of self-contained AC units with chilled water or a central air system.

6.4.3.2 M&V Option Selection Rationale

Savings vary based on many parameters including existing equipment efficiency, cooling 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 to evaluate the savings from the installation of chilled water or a central air system.

During ECM development, the model will serve to establish the baseline and predict the post-retrofit energy consumption based on the ECM's effects within the model. The energy model will be calibrated with past utility data and spot measurements in order to develop an acceptable baseline representation and ultimately predict energy savings. The recorded key parameter data will be used as inputs to the model. Performance parameters (Table 6-4.3) include unit power. This would be obtained for the baseline development by measuring unit kilowatts; however, it may be necessary to determine the difference in flow and temperature 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 (runtimes) 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 runtimes during the baseline development and post-installation. These data will be used to verify AHU-modeled operation. The performance period savings will be based on validation of post-installation findings through short-term measurements.

Table 6-4.3. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Unit Power			
Performance	Baseline	All AC units over 3 tons (kW)	Short-term measurement
Performance	Post-Installation	All AC units over 3 tons (flow times temperature delta)	Short-term measurement
Performance	Performance	10% rotating among units	Short-term measurement
Runtime			
Operational	Baseline	All AC units over 3 tons	Short-term measurement
Operational	Post-Installation	All AC units over 3 tons	Short-term measurement
Operational	Performance	Based on post-installation	Short-term measurement

6.4.3.3 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.
- Customer witnessing of M&V activities.

6.4.4 ECM: AIR SOURCE HEAT PUMPS

This measure involves switching from packaged AC/gas furnace units to air source heat pumps (ASHP). ASHP absorb and extract heat from outdoor air to provide heating and cooling to buildings. Savings are the result of the higher efficiency of ASHP compared to baseline equipment; in some cases, this measure may result in switching fuel sources (e.g., natural gas to electricity). The performance of ASHP varies based on ambient air temperature and supply air temperature needed for heating or cooling the building.

6.4.4.1 M&V Plan Description

Option B is recommended to validate ECM performance during the performance phase, with electricity use measured continuously. On an annual basis, electrical use is aggregated by month, and the aggregate monthly electrical use is correlated to a linear function of monthly heating degree days (HDD) and monthly cooling degree days (CDD): $Em = E0 + a*HDD + b*CDD$. Electrical use is then normalized using the monthly heating and cooling degree days in a typical meteorological year (TMY) for the site. Fuel savings is calculated based on the natural gas use and electrical use of the baseline equipment in a TMY for the site, established using similar correlations of monthly natural gas and electric use with heating degree days, and monthly electrical use with cooling degree days for the baseline equipment.

6.4.4.2 M&V Option Rationale

Savings vary based on many parameters including existing equipment efficiency, heating load, cooling load, part-load HVAC performance, and run hours. Due to the multiple interactions between HVAC equipment and building load it is recommended to develop regression models to evaluate the savings during a typical year (using TMY data) at the site from the installation of ASHP.

During ECM development, the regression model will serve to establish the baseline. Post-retrofit energy consumption will be estimated using operating curves from the equipment manufacturer.

Performance parameters (Table 6-4.4) include combustion efficiency tests on all heating equipment during baseline development. If the measure involves utilizing the proposed ASHP to replace the existing cooling system, appropriate baseline measurements related to the existing cooling system efficiency and its run time need to be collected. Specific baseline measurements will depend on the existing heating and cooling equipment. The run times are established by measuring the hours that the boiler and the existing cooling system runs at various loads. The post installation efficiency of the ASHP shall be monitored continuously during the performance period under different operating conditions.

Table 6-4.4. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Natural Gas Use			
Performance	Baseline	All packaged units	Spot check at various loads
Electrical Use			
Operational	Baseline	All packaged units	Measure monthly electrical use
Operational	Post-Installation	All ASHP	Measure monthly electrical use
Operational	Performance	All ASHP	Measure monthly electrical use

6.4.4.3 M&V Performance Assurance Activities

- Verify installation of ASHP.
- Verify ASHP are operating as intended via efficiency tests.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Customer witnessing of M&V activities.

6.5 LIGHTING IMPROVEMENTS

Measures under this technology category address improvements related to lighting systems including, but not limited to, interior and exterior lighting retrofits and replacements, intelligent lighting controls and timers, occupancy/vacancy sensors, light emitting diode (LED) technologies, daylighting, spectrally enhanced lighting, fiber optic lighting technologies, and interior surface reflective lighting improvements.

6.5.1 ECM: LIGHTING

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.

6.5.1.1 M&V Plan Description

Option A is recommended to validate ECM performance during the performance period through measurement of key parameter(s) in order to quantify the energy savings associated with the lighting upgrades.

6.5.1.2 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 for equipment variants that make up a relatively small percentage (e.g., less than 20%) of the of the baseline-connected load.

Depending on customer preference, performance period parameters (Table 6-5.1) may be measured during the performance period or may be based on post-installation measurements taken in conjunction with commissioning.

Table 6-5.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Lighting Power (kW)			
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20)	Spot measurement
Performance	Post-Installation	90/10 or 80/20	Spot measurement
Performance	Performance	90/10 or 80/20	Operational verification through visual inspection
Lighting Levels (foot-candles/lumens)			
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20)	Spot measurement
Performance	Post-Installation	90/10 or 80/20	Spot measurement
Performance	Performance	90/10 or 80/20	Operational verification through visual inspection
Lighting Runtime (hours per location)			
Operational	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision	Short-term measurements
Operational	Post-Installation	Measured during baseline period	Stipulated – same as baseline period
Operational	Performance	Measured during baseline period	Stipulated – same as baseline period

Baseline and post-installation performance parameters for a sample set of fixtures (power level of lamp and ballast combinations) should be spot measured, focusing on the more typical or larger group of lamps being installed. Ideally, fixtures that represent at least 75% of the lighting energy use should be measured.

Baseline operational parameters (hours of operation of the lighting system) should be verified via short-term data logging, focusing on typical spaces that represent the largest areas in the facility. Ideally, spaces that represent at least 80% of the lighting energy use should be measured.

Baseline and post-installation lighting levels should be verified by spot measurements to meet desired confidence and precision. The lighting levels need to meet the customer's design illumination levels.

Calculations of savings should consider heating/cooling load impacts.

6.5.1.3 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.
- Obtain approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Customer witnessing of M&V activities.

6.5.2 ECM: LIGHTING CONTROLS

This ECM involves installing controls on existing lighting systems to reduce operating (runtime) hours through implementation of occupancy sensors, daylighting controls, exterior photocells, and improved programmed runtimes.

6.5.2.1 M&V Plan Description

Option A is recommended to validate ECM performance during the performance period through measurement of selected key parameter(s). The lighting retrofit may consist of installation of new lighting controls that will reduce runtimes or dim lighting through standard lighting measures. Fixture power measurement procedures will be identical to those outlined in the lighting ECM (Section 6.5.1).

6.5.2.2 M&V Option Selection Rationale

Implementation of lighting control technologies allow for the capture and quantification of changes in performance and operational parameters needed to calculate energy savings.

Performance parameters (lighting power kW) can be spot measured via a sampling plan. Operational parameters should be verified via short-term data logging (Table 6-5.2).

Baseline and post-installation performance parameters for a sample set of fixtures (power level of lamp and ballast combinations) should be spot measured during the baseline development and post-installation period.

Baseline and post-installation operational parameters (hours of operation of the lighting system) should be verified via short-term data logging conducted during the baseline development and post-installation. The baseline (no controls) coefficient of variation (Cv) is assumed to be 0.5. For post-installation measurements, the Cv is assumed to be 1.0 for spaces controlled by motion sensors and 0.5 for all other controls.

Table 6-5.2. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Lighting Power (kW)			
Performance	Baseline	90% confidence with 10% precision or80% confidence with 20% precision (90/10 or 80/20)	Spot measurement
Performance	Post-Installation	Measured during baseline period	Same as baseline period
Performance	Performance	Measured during baseline period	Same as baseline period
Lighting Levels (foot-candles/lumens)			
Performance	Baseline	Daylighting only / Full operation for exterior	Spot measurement
Performance	Post-Installation	Daylighting only / Full operation for exterior	Spot measurement
Performance	Performance	Verified at post-installation (spot measurement)	None
Lighting Runtime (hours per location)			
Operational	Baseline	90/10 or 80/20	Short-term measurements
Operational	Post-Installation	90/10 or 80/20	Short-term measurements
Operational	Performance	Measured during baseline and post-installation period	Operational verification for representative sample

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

6.5.2.3 M&V Performance Assurance Activities

- Confirm that installed occupancy sensors, daylighting controls or exterior photocells 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 and levels are maintained as operational over the term of the project.
- Perform annual visual 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.
- Customer witnessing of M&V activities.

6.6 BUILDING ENVELOPE MODIFICATIONS

Measures under this technology category include any improvements related to building envelope components and systems including, but not limited to, installation of insulation, weatherization, window replacement, reflective solar window tinting, and shading devices and enhancements.

6.6.1 ECM: BUILDING ENVELOPE IMPROVEMENTS

This measure involves upgrading the building envelope to reduce heat transfer, radiative gain from the sun, and/or infiltration.

6.6.1.1 M&V Plan Description

Option A is recommended for ongoing verification of the performance of this ECM.

6.6.1.2 M&V Option Selection Rationale

Savings associated with this measure can be calculated using a calibrated building energy analysis model. The baseline model is calibrated to utility bills or short-term metered data.

Performance parameters (Table 6-6.1) include the calculation of the envelope R-value or window (glazing) U-value using ASHRAE 90.1 standards, and the solar heat gain coefficient (SHGC) using the test method developed by the National Fenestration Rating Council (NFRC). The R-value and SHGC should be calculated based on building construction (e.g., building materials, insulation levels) found during the baseline development and again based on post- installation improvements. These values should be the parameters used within the model to calculate energy savings.

Operational parameters (Table 6-6.1) include building temperature set points, setbacks, schedules, etc. Key operational parameters should be short-term metered to verify that only the improvement in R-value or U-value and reduced infiltration are being applied to savings. Reduced equipment runtime should also be verified.

Table 6-6.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Conduction			
Performance	Baseline	Insulation R-value with framing (entire structure) and/or U-value (glazing)	Calculated using ASHRAE calculation methodologies
Performance	Post-Installation	Insulation R-value with framing (entire structure) and/or U-value (glazing)	Calculated using ASHRAE calculation methodologies
Performance	Performance	None	Visual verification
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	Visual verification
Operating Hours			
Operational	Baseline	Buildings/areas affected by the ECM	EMCS/loggers
Operational	Post-Installation	Buildings/areas affected by the ECM	Same as baseline
Operational	Performance	Buildings/areas affected by the ECM	Operational verification through visual inspection

The model will ultimately predict energy savings. During ECM development, the model will serve to establish the baseline and predict the post-retrofit energy consumption based on the

ECM's effects within the model. The energy model will be calibrated with past utility data and spot measurements in order to develop an acceptable baseline representation. The recorded data will be used as inputs to the model.

6.6.1.3 M&V Performance Assurance Activities

- Verify installation of improved building envelope material.
- Perform standard ASHRAE and NFRC calculations to verify reduced heat transfer, infiltration, and solar heat gain.
- 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.
- Customer witnessing of M&V activities as appropriate.

6.7 CHILLED WATER, HOT WATER, AND STEAM DISTRIBUTION SYSTEMS

Measures under this technology category include improvements related to chilled water, hot water and steam distribution systems including, but not limited to, installation of piping insulation, hot water heater repair and replacement, steam trap repair and replacement, and repair or replacement of existing condensate return systems and installation of new condensate return.

6.7.1 ECM: STEAM TRAP REPLACEMENT

This measure involves replacing steam traps. Savings are the result of eliminating leaks or failed traps. This will improve the amount of returned water and its temperature, which will reduce boiler energy consumption and water treatment chemicals for makeup water.

6.7.1.1 M&V Plan Description

Option A is recommended for ongoing verification of the performance of this ECM.

6.7.1.2 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.

Performance parameters (Table 6-7.1) 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 and post-installation, and during the performance period 20% of the steam traps will be assessed every year and the sampled population rotated each year.

Table 6-7.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Steam Trap Assessment			
Performance	Baseline	Entire facility	Thermograph/ultrasonic assessment
Performance	Post-Installation	Entire facility	Thermograph/ultrasonic assessment
Performance	Performance	20% rotating	Thermograph/ultrasonic assessment, verify that identified failed traps have been replaced
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	Stipulated – same as baseline
Steam Trap Operation			
Operational	Baseline	Entire facility	Hours, seasonal use based on boiler logs
Operational	Post-Installation	Based on baseline	Stipulated – same as baseline period
Operational	Performance	Based on baseline	Stipulated – same as baseline period

6.7.1.3 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 through annually rotating steam-trap assessments.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Customer witnessing of M&V activities.

6.8 ELECTRIC MOTORS AND DRIVES

Measures under this technology category include improvements to electric motors and drives including, but not limited to, replacement of motors with high efficiency motors, and installation of variable speed drives.

6.8.1 ECM: PREMIUM EFFICIENCY MOTORS

This measure involves replacing standard efficiency motors with National Electrical Manufacturers Association (NEMA) premium efficiency motors. Savings are the results of improved efficiency.

6.8.1.1 M&V Plan Description

Option A is recommended to validate ECM performance during the performance period through the measurement of key parameter(s) to quantify the energy consumption savings associated with premium efficiency motors. Savings will be based on kilowatt reduction by installing more efficient motor(s).

6.8.1.2 M&V Option Selection Rationale

Savings associated with the installation of premium efficiency motors are a function of improved efficiency, run hours, and motor kilowatts.

Performance parameters to be collected are motor kilowatts through spot measurement (Table 6-8.1) and runtime through short-term metering, where applicable. These measurements will be completed during the baseline development and post-installation. Performance period savings are based on spot-metering motor kilowatts during post-installation and calculated efficiency. 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 runtime; Table 6-8.1) will be determined during the short-term data logging conducted for a representative number of the existing motors during the baseline development. The performance period savings will be based on baseline findings.

Table 6-8.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Motor Power Information			
Performance	Baseline	Collect nameplate data on all motors; measure kilowatts at various load conditions	Spot measurement
Performance	Post-Installation	Collect nameplate data on all motors; measure kilowatts at various load conditions	Spot measurement
Performance	Performance	Based on post-installation M&V measurements	Operational verification based on visual inspection
Motor Runtime (hours)			
Operational	Baseline	20% (focus on large motors >20 hp)	Short-term metering
Operational	Post-Installation	Based on baseline measurements	Stipulated – same as baseline
Operational	Performance	Based on baseline measurements	Stipulated – same as baseline

6.8.1.3 M&V Performance Assurance Activities

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

6.8.2 ECM: VARIABLE SPEED PUMPING

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

6.8.2.1 M&V Plan Description

Option A is recommended to validate ECM performance during the performance period through measurement of selected key parameter(s). Pump flow is established using short-term measurements or performance curves, while pump power and runtimes are established using short-term measurements.

6.8.2.2 M&V Option Selection Rationale

Installing VSDs on pumps is a standard ECM with demonstrated savings. However, each system is slightly different from one another, and savings vary based on system design, existing controls, proposed controls, and system requirements. Savings will be determined from the reduced post-installation kilowatts from speed reduction and by applying the recorded (logged) run hours.

Performance parameters (Table 6-8.2) include pump power during the baseline development, post-installation, and performance period. It is recommended to perform short-term measurements and rotate through a small percentage of the pumps each year during the performance period.

Operational parameters (runtime, 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 runtime and flow and that a constant discharge pressure is being maintained during the baseline development and post-installation. 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 post-installation findings. A constant discharge pressure demonstrates that the system performance requirements are being met and that the VSD is operating as intended.

Table 6-8.2. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Pump Power (kW; runtime based on measurement)			
Performance	Baseline	100% on pumps included in scope	Short-term measurements
Performance	Post-Installation	100% on pumps included in scope	Short-term measurements or from EMCS
Performance	Performance	20% rotating	Short-term measurements or from EMCS
Pump Flow (GPM)			
Operational	Baseline	100% on pumps included in scope	Short-term measurements or based on pump curves
Operational	Post-Installation	100% on pumps included in scope	Short-term measurements or based on pump curves
Operational	Performance	Based on post-installation	Stipulated – based on post-installation
Pump Discharge Pressure (PSIG)			
Operational	Baseline	100% on pumps included in scope	Short-term measurements
Operational	Post-Installation	100% on pumps included in scope	Short-term measurements
Operational	Performance	Based on post-installation	Stipulated – based on post-installation

6.8.2.3 M&V Performance Assurance Activities

- Verify installation of VSDs and controls.
- Perform review of system operation with short-term metering or measurements on pump power, runtime, and discharge pressure.

- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Customer witnessing of M&V activities.

6.9 REFRIGERATION

Measures under this technology category include improvements to refrigeration systems including, but not limited to, installation or replacement of ice/refrigeration equipment with high efficiency units.

6.9.1 ECM: High-Efficiency Refrigeration Equipment

This measure involves replacing once-through water-cooled refrigeration equipment with air-cooled equipment. Savings are the results of improved energy and water efficiency.

6.9.1.1 M&V Plan Description

Option A is recommended to validate ECM performance during the performance period through the measurement of key parameter(s) to quantify the energy consumption and water savings associated with refrigeration equipment replacement. Savings will be based on reduced water use and improved energy efficiency of installed equipment.

6.9.1.2 M&V Option Selection Rationale

Savings associated with the installation of high-efficiency refrigeration equipment are a function of improved efficiency, run hours, and reduced water consumption.

Performance parameters to be collected are compressor kilowatts through spot metering (Table 6-9.1) and runtime through short-term metering, where applicable at different loads. These measurements will be completed during the baseline development and post-installation phases. Performance period savings are based on spot-metering motor kilowatts during post-installation and calculated efficiency at different load conditions.

Operational parameters (power and runtime; Table 6-9.1) will be determined during the short-term data logging conducted for a representative number of the existing equipment during the baseline development at different loads. The performance period savings will be based on post-installation measurement results.

Water consumption will be determined through short-term measurements of the flowrate on a representative sample of refrigeration equipment. As water-cooled equipment will be retrofit with air-cooled equipment, post-installation verification is accomplished by visual inspection to ensure water flow was eliminated.

Table 6-9.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Refrigeration Unit Information			
Performance	Baseline	Collect nameplate data on all refrigeration equipment; measure kilowatts at various load conditions	Spot measurements

Parameter	Period	Population	Activity
Performance	Post-Installation	Collect nameplate data on all refrigeration equipment; measure kilowatts at various load conditions	Spot measurements
Performance	Performance	Based on post-installation M&V measurements	Operational verification based on visual inspection
Compressor Runtime (hours)			
Operational	Baseline	Measure compressor runtime on sample set of equipment (refrigerators, freezers) at different loads	Short-term measurements
Operational	Post-Installation	Measure compressor runtime on sample set of equipment (refrigerators, freezers) at different loads.	Short-term measurements
Operational	Performance	Based on post installations measurements	Stipulated – same as post-installation
Water Reduction (gpm)			
Operational	Baseline	Measure water flowrate on sample set of equipment (refrigerators, freezers)	Short-term measurements
Operational	Post-Installation	Based on baseline measurements	Visual inspection to verify elimination of water flow
Operational	Performance	Based on post-installation verification	Stipulated

6.9.1.3 M&V Performance Assurance Activities

- Verify installation and operation of the refrigeration equipment.
- Use measured kilowatts and compressor runtime to verify savings.
- Customer witnessing of M&V activities.
- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.

6.10 DISTRIBUTED GENERATION

Measures under this technology category include improvements or installations related to distributed generation including, but not limited to, installation of cogeneration systems, micro-turbines, and fuel cells. For renewable energy distributed generation: DOE Technology Category 11 and Section 6.11 in this document.

6.10.1 ECM: COMBINED HEAT AND POWER

This measure involves the installation of a combined heat and power (CHP) plant. Savings are a result of displacing electricity purchased from the utility and reductions in heating energy by using waste heat from the installed CHP plant.

6.10.1.1 M&V Plan Description

Option B is recommended to validate ECM performance during the performance period through measurement of key parameters. The intent of the M&V activities is to verify the key equipment performance for the proposed CHP in comparison with the baseline boiler that's used for generating the thermal energy. Baseline energy use is a combination of electricity and natural gas or other fuel resource that's used by the boiler to generate hot water for domestic usage or

HVAC. Boiler loads will be established using boiler logs from the baseline period and/or other data to capture the demand associated with demand for hot water or steam. This could be done through trending this relevant data through EMCS and metering of gas or fuel oil or other fuels. The fuel savings shall be calculated based on the calculated boiler loads and energy efficiency of the boilers and the baseline equipment. Post-installation energy use will be based on continuously metering electricity and the thermal output at the CHP system after accounting for any parasitic losses along with the natural gas or other fuel input to the CHP system.

6.10.1.2 M&V Option Selection Rationale

The overall savings associated with this measure vary based on weather conditions, existing equipment type, efficiencies, run times and controls.

For the baseline boiler, the performance will be assessed by measuring the efficiencies at different loads during the baseline, post implementation and performance phases of the project. The operational data for the boilers will be based on the boiler logs and trend data from the EMCS established during the baseline phase. For the CHP system during the post installation and performance period, performance/operations will be assessed by metering the electricity generation and thermal output from the CHP system, along with the electricity consumed to run the CHP system, fuel consumption by the CHP system and hot water/thermal energy from the CHP system in terms of flow and water temperature (Table 6-10.1). This data can be used to track the uptime of the CHP system to assess its reliability.

Table 6-10.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Boiler Combustion Efficiency			
Performance	Baseline	All boilers	Spot check at various loads
Performance	Post-Installation	All boilers	Spot check at various loads
Performance	Performance	All boilers	Spot check at various loads
Operating Hours			
Operational	Baseline	All boilers	Operating hours at each load factor
Operational	Post-Installation	All boilers	Stipulated – same as baseline period
Operational	Performance	All boilers	Stipulated – same as baseline period
CHP System Efficiency (fuel consumption, electricity generation, thermal output)			
Performance/Operational	Post-Installation	All CHP	Short-term/continuous
Performance/Operational	Performance	All CHP	Continuous metered data

6.10.1.3 M&V Performance Assurance Activities

- Verify operation of CHP system
- Submeter the CHP system to verify energy production, consumption and thermal output, along with the uptime or availability of the CHP system which can calculated by the time series data for the electricity and thermal output

- Obtain customer approval of all assumed/stipulated performance and operational parameters for the baseline boiler system
- Customer witnessing of M&V activities.

6.11 RENEWABLE ENERGY SYSTEMS

Measures under this technology category include the installation or repair of renewable energy systems including, but not limited to, photovoltaic systems (may include battery storage systems); solar hot water, solar ventilation preheating, or passive solar heating systems; wind energy systems; landfill gas, wastewater treatment plant digester gas, and coal bed methane power plant systems; biomass system, using wood waste and other organic waste streams for heating and/or electrical generation; replacement of air conditioning and heating units with ground coupled heat pump systems (aka geothermal heat pumps); ESPC Energy Sales Agreements, or renewable energy distributed generation systems.

6.11.1 ECM: RENEWABLE GENERATION

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. Savings are the result of offsetting current facility electricity consumption.

6.11.1.1 M&V Plan Description

Option B is recommended to validate ECM performance and ongoing verification during the performance period through measurement of energy generated.

6.11.1.2 M&V Option Selection Rationale

The overall savings associated with this measure can be easily quantified by continuously measuring the generated (electrical) power from the renewable energy source. The renewable energy electricity production is metered through a production (revenue grade) meter and, when applicable, may also utilize a net meter to track any exports to the grid.

There are no baseline M&V activities as this ECM adds new generation assets; savings are the result of energy produced by the asset that offsets energy that would have been purchased.

Performance parameters (Table 6-11.1) include the measurement of the energy generated from the renewable source. Energy generation is to be sub-metered and measured throughout the performance period.

An analysis of the metered data will be completed each year to verify generated savings.

Table 6-11.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Generated Kilowatts and Kilowatt-Hours (run hours based on measurement)			
Performance/Operational	Baseline	None	None
Performance/Operational	Post-Installation	Renewable energy asset(s)	Short-term/continuous
Performance/Operational	Performance	Renewable energy asset(s)	Continuous metered data

6.11.1.3 M&V Performance Assurance Activities

- Inspections of renewable energy system to ensure proper operation and maximum performance.
- 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.
- Customer witnessing of M&V activities.

6.11.2 ECM: RENEWABLE ENERGY OFFSET

This measure involves installing a renewable energy source to offset current thermal energy consumption. This includes solar thermal, ground-source heat pumps, and other renewable energy systems that offset existing equipment runtime and improve efficiency. Savings are the result of reduced thermal energy from existing equipment or purchased from the utility.

6.11.2.1 M&V Plan Description

Option B is recommended to validate ECM performance during the performance period through metering of key parameters. A calibrated model is recommended to quantify the energy savings associated with offsetting thermal energy consumption with a renewable energy source.

6.11.2.2 M&V Option Selection Rationale

The overall savings associated with this measure vary based on load, weather conditions, existing equipment type, efficiencies, and controls.

Performance parameters (Table 6-11.2) 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, post-installation, and performance period.

Operational parameters (Table 6-11.2) include runtime, which will be collected during the baseline development, post-installation, and performance period.

Table 6-11.2. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Equipment Efficiency and Runtime (hours)			
Performance/Operational	Baseline	Existing equipment	Short-term metering
Performance/Operational	Post-Installation	Renewable energy source(s)	Short-term metering
Performance/Operational	Performance	Renewable energy source(s)	Metering

6.11.2.3 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.
- Customer witnessing of M&V activities.

6.12 ENERGY/UTILITY DISTRIBUTION SYSTEMS

Measures under this technology category include improvements related to energy or utility distribution systems including, but not limited to, installation of transformers, power quality upgrades, power factor correction, or gas distribution systems.

6.12.1 ECM: ELECTRICAL TRANSFORMER REPLACEMENT

This ECM involves replacing standard efficiency with high efficiency electrical transformers. The new transformers will reduce energy losses leading to both electricity consumption (kWh) and demand (kW) savings. The new transformers will also contribute to improved power factor and operate cooler than the standard efficiency equipment.

6.12.1.1 M&V Plan Description

Option A is recommended to validate ECM performance during the performance phase. The performance of this measure is evaluated by measuring the efficiency of the transformers on a sample during the baseline and post implementation along with hours of operation at different loads.

6.12.1.2 M&V Option Selection Rationale

This effects the load and schedule of the effected equipment, which are variable during both the baseline and post retrofit phases. Both the load and the time the transformers operate at each of the loads are critical to evaluate the performance of these transformers. Hence Option A, retrofit isolation with key parameter measurement with sampling is recommended for this ECM.

The baseline for this ECM will be developed thorough detailed audit of the transformers at the facility. The audit should include measurements and trended data to show the energy losses in the transformer at different loads based on sampling to ensure a minimum of 80% confidence with 20% precision levels. This trended information will be extrapolated to the remaining transformers. The hours at different loads for these transformers will also be measured based on a sampling based on a minimum of 80% confidence and 20% precision levels.

The post-installation energy profile for the new transformers will be measured and trended at different loads on a sample of transformers based on a minimum of 80% confidence and 20% precision levels. These measurements will show the post-installation energy losses in the transformer at different loads. This trended information will be extrapolated to the remaining transformers.

The difference between the baseline measured transformer losses and the post-Installation measured transformer losses determines the savings for this ECM. The savings calculations will be updated prior to acceptance using the measured post-Installation data.

For the remainder of the performance period, a sample of transformers will be inspected and tested annually via infrared imaging for connection integrity with provided documentation. These activities and other relevant information will be provided in the Annual M&V Report.

Table 6-12.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Power (kW)			
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20)	Short-term metering to capture efficiencies at different loads
Performance	Post-Installation	90/10 or 80/20	Short-term metering to capture efficiencies at different loads
Performance	Performance	90/10 or 80/20	Inspect and test annually via infrared imaging for connection integrity
Runtime (hours at each load)			
Operational	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision	Short-term metering to measure the operating hours at different loads
Operational	Post-Installation	Measured during baseline period	Stipulated – same as baseline period
Operational	Performance	Measured during baseline period	Stipulated – same as baseline period

6.12.1.3 M&V Performance Assurance Activities

- Verify installation and operation of transformers.
- Inspect and test a sample of installed transformers for connection integrity.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Customer witnessing of M&V activities.

6.13 WATER AND WASTEWATER CONSERVATION SYSTEMS

Water conservation measures (WCMs) under this technology category include improvements related to water and wastewater systems including, but not limited to, installation of high-efficiency plumbing fixtures: toilets, urinals, faucets, and showerheads; water efficient irrigation and landscaping; on-site sewer treatment systems; distribution system leak detection and repair; cooling tower and steam boiler system water management; water-efficient vehicle wash systems; water-efficient commercial kitchen equipment; water-efficient laboratory and medical equipment; alternative water systems (e.g., rainwater harvesting, reclaimed wastewater, and condensate capture systems); xeriscape/low water consuming vegetation; or deduct meters (to remove wastewater charges for irrigation and cooling tower (evaporated) water).

6.13.1 ECM: PLUMBING AND INDOOR WATER EQUIPMENT

This measure involves the retrofit of plumbing fixtures and/or other indoor water-consuming appliances such as commercial kitchen equipment, clothes washers, and medical and laboratory equipment. These WCMs include indoor water equipment that has regular water use patterns and efficiency gains where water savings can be easily estimated with limited measurement. These include (but are not limited to) the following categories:

- Plumbing fixtures: high-efficiency urinals, water closets, faucets and showerheads. Some of this equipment is labeled by the Environmental Protection Agency's (EPA) WaterSense program[42].
- Commercial kitchen equipment: high-efficiency ice machines, pre-rinse spray valves, dishwashing, and food steamers. Many of these product types are labeled by the EPA ENERGY STAR program[43], as they conserve energy along with water.
- Laundry equipment: high-efficiency residential clothes washing machines, also covered by the ENERGY STAR program.
- Medical and laboratory equipment: high-efficiency disinfection, steam sterilizing equipment, and glass and vivarium washing equipment.

Water equipment not suitable for this option include engineered processes that have relatively large water use (compared to the total building or facility water use), including vehicle wash systems, vacuum systems and water purification. See the section on Process Water Equipment for these equipment types.

6.13.1.1 M&V Plan Description

Option A is recommended to validate ECM performance during the performance period through measurements of water flow pre- and post-installation.

6.13.1.2 M&V Option Selection Rationale

Water use per plumbing fixture/equipment can be measured and total water use estimated using industry standards based on building occupancy, usage patterns and equipment ratings (flow rates and flush rates). If the number of fixtures is large, extensive ongoing M&V may not be

[42] EPA WaterSense Program: https://www.epa.gov/watersense
[43] EPA ENERGY STAR Program: https://www.energystar.gov/

cost-effective. Performance and operational parameters can be mutually agreed upon and used to estimate annual savings, reducing the cost to verify the performance of the WCM.

Conduct a water balance and compare to the facility water use to ensure baseline and savings are within the expected range.[44] Perform a one-time, post-installation measurement of a sample set of fixture/equipment water flow (gallons per minute, gallons per flush, or gallons per batch use) if practical.[45]

Performance and operational parameters for this WCM (Table 6-13.1) will be determined using measurements, field survey information, customer provided historical water consumption records, equipment ratings and industry standards of equipment operational patterns.

Table 6-13.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Water Usage per Measure			
Performance	Baseline	90% confidence with 10% precision or 80% confidence with 20% precision (90/10 or 80/20)	Spot or short-term measurements
Performance	Post-Installation	90/10 or 80/20	Spot or short-term measurements
Performance/ Operational	Performance	90/10 or 80/20	Operational verification through visual inspection

6.13.1.3 M&V Performance Assurance Activities

- Perform an annual visual inspection of sample set of installed fixtures/equipment in selected facilities to ensure integrity of devices in affected buildings and that WCM retains potential to perform.
- Obtain customer approval of all stipulated operational parameters shown.
- Customer witnessing of M&V activities.

6.13.2 ECM: WATER METERING

This measure involves installing water meters such as cooling tower deduct meters, meters on other high demand water using applications (e.g., irrigation, central plants), and building water meters. This measure is typically only for facilities with a large central plant with centralized cooling towers. Savings are a result of capturing reductions in sewer discharge, thereby reducing sewer charges and/or identifying leaks in high demand applications or building water use.

[44] FEMP's Water Balance Tool may be used to estimate water use of specific end-uses, which can be accessed on the FEMP Water Management website https://www.energy.gov/femp/articles/water-evaluation-tools

[45] A technique to estimate the flush rate of commercial flush-valve toilets and urinals is to time the flush cycle. For example, a standard 1.6 gallon per flush rated toilet should have a flush cycle time of approximately 4 to 5 seconds. FEMP Toilet and Urinal Best Management Practice: https://www.energy.gov/femp/best-management-practice-6-toilets-and-urinals

6.13.2.1 M&V Plan Description

Option B is recommended to validate ECM performance and ongoing verification during the performance period through measurement using installed water meters.

6.13.2.2 M&V Option Selection Rationale

For cooling tower deduct meters, the overall cost savings can easily be quantified by performing a utility bill analysis and verifying the reduced sewer charge due to metering the makeup water supplied to the cooling towers and metering the blowdown water. The difference between the volume of water measured by the makeup meter and blowdown meter is the evaporative water used for the cooling process. This difference can be claimed as sewer charge savings. For meters on high demand applications such as irrigation or central plants and for building-level meters the cost savings can be quantified if there are leaks and losses this measure will help mitigate. In this case, the leaks and losses can be established by engineering estimates or spot measurements. Find methods to estimate leak and losses in the Water Meter Measurement and Verification Best Practice.

By collecting the proper water utility data, the run time of the metered application (e.g., irrigation, central plants, and other high demand applications) will also be verified through metered data. This will be accomplished during baseline development, post-installation, and the performance period.

Performance and operational parameters for this ECM (Table 6-13.2) include the verification of reduced sewer charges for cooling tower deduct meters and reduced supply water charges for high demand water using applications and building metering.

Table 6-13.2. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Cooling Tower Deduct Metering			
Performance/Operational	Baseline	Cooling tower makeup water and cooling tower blowdown	Spot or short-term metering
Performance/Operational	Post-Installation	Cooling tower makeup water and cooling tower blowdown	Metered data
Performance/Operational	Performance	Cooling tower makeup water and cooling tower blowdown	Metered data
High Demand Water Using Applications			
Performance/Operational	Baseline	High demand water using application supply meter	Spot or short-term metering
Performance/Operational	Post-Installation	High demand water using application supply meter	Metered data
Performance/Operational	Performance	High demand water using application supply meter	Metered data

6.13.2.3 M&V Performance Assurance Activities

- Verify installation and proper operation of meter(s), including calibration if necessary.
- Obtain customer approval of all stipulated performance and operational parameters shown in the baseline and post-installation parameter value tables.

- For additional details on M&V protocols for water meters, go to *Water Meter Measurement and Verification Best Practice*[46].
- Customer witnessing of M&V activities.

6.13.3 ECM: PROCESS WATER EQUIPMENT

This measure involves replacing existing process equipment that use water as a working fluid with more efficient equipment (e.g., systems that use less energy and water to meet the same demand).

This includes (but is not limited to) the following:

- **Cooling towers:** open-recirculating units that rely on evaporation to provide comfort or process cooling.
- **Single-pass cooling:** water circulates through a heat exchanger or piece of equipment once before being discharged.
- **Steam boilers:** pressurized vessels that use heat to turn water into steam for a variety of applications.
- **Water-cooled vacuum pumps:** mechanical system that use a water-cooled pump to draw air from a sealed chamber to create a low-pressure environment.
- **Vehicle wash:** designated location for rinsing government and military vehicles or aircraft or locations on government property for washing personally owned vehicles.
- **Industrial washing stations:** washing or rinsing stage in an industrial production process.
- **Water purification systems:** systems used to treat or purify water to meet desired water quality requirements for specific application purposes or to meet discharge requirements.

6.13.3.1 M&V Plan Description

Option B is recommended to validate ECM performance and ongoing verification during the performance period through measuring water system consumption savings associated with improved process equipment efficiency over time.

6.13.3.2 M&V Option Selection Rationale

Process water equipment performance will vary by design, controls, operational parameters, and system requirements. Savings vary based on many parameters including existing equipment efficiency, cooling load, heating load, part-load HVAC performance for cooling and heating equipment and run hours.

Spot, short-term, or continuous metering of process water equipment is appropriate to establish baseline performance, verify savings, and validate ongoing performance of these efficiency

[46] Available at https://www.pnnl.gov/publications/water-meter-measurement-and-verification-best-practice

improvements. Continuous monitoring of key parameters can be used to improve or optimize operation of the equipment over time, thereby improving performance of the retrofit.

Performance and operational parameters (Table 6-13.3) include water usage and run time. This would be obtained for the baseline development by measuring unit water usage. For cooling towers, steam boilers, and single pass cooling it is also recommended to monitor a small portion of installed equipment that requires cooling or heating (e.g., HVAC equipment or other process equipment) to verify proper operation and rotate these measurements among equipment. For vacuum pumps it is also recommended to spot measure vacuum levels. These will be collected via spot measurement or short-term data logging.

Table 6-13.3. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Water Usage and Runtime (hours)			
Performance/ Operational	Baseline	Water supply on all cooling towers, steam boilers, single pass cooling, vacuum pumps, vehicle and industrial wash systems, and water purification equipment	Spot/short-term measurement
Performance/ Operational	Post-Installation	Water supply on all cooling towers, steam boilers, single pass cooling, vacuum pumps, vehicle and industrial wash systems, and water purification equipment	Spot/short-term measurement/continuous metered data
Performance/ Operational	Performance	Water supply on all cooling towers, steam boilers, single pass cooling, vacuum pumps, vehicle and industrial wash systems, and water purification equipment	Spot/short-term measurement/continuous metered data

6.13.3.3 M&V Performance Assurance Activities

- Verify proper installation and performance of process water equipment.
- Review process equipment operation with short-term metering or measurement of water use and run time.
- Obtain customer approval of all performance and operational parameters shown.
- Customer witnessing of M&V activities.

6.13.4 ECM: IRRIGATION SYSTEMS

This measure involves implementing improvements to the efficiency of irrigation systems. Irrigation systems include all components that deliver and control the application of supplemental water in landscapes. System components include piping infrastructure, valves, sprinkler heads, and irrigation controls. There are generally two types of measures for irrigation:

- **Efficient irrigation system and improvements:** replacement of irrigation system components and/or improvements to existing systems that improve the uniform distribution of water to meet landscape irrigation requirements and minimize waste and losses from the system.[47]

[47] Irrigation efficiency is defined as the percentage of irrigation water that is stored in the soil and available for use by the landscape as compared to the total amount of water provided to the landscape.

- **Advanced irrigation controls and real-time sensors**: advanced controls and sensors (e.g., rain, wind, and freeze sensors) that use real-time data for landscape irrigation based on local conditions, which can reduce irrigation run-time and overall water use.

6.13.4.1 M&V Plan Description

Option B is recommended to validate ECM performance and ongoing verification during the performance period through measurement of water consumption associated with improved irrigation system efficiency, advanced irrigation controls and real-time sensors.

6.13.4.2 M&V Option Selection Rationale

The overall savings associated with this measure can be quantified by measuring the volume of water supplied by the irrigation system. Note, there may be energy savings associated water reduction due to a decrease in pump run-time. The contractor should follow the M&V protocol appropriate for a pump related ECM.

Inspect the irrigation system during post-installation to ensure design specifications are met including system distribution uniformity, irrigation system precipitation rates, pressure, valve operation, and backflow prevention. Follow guidelines using the Irrigation Association Irrigation Audit Guidelines.

Verify that advanced controllers at post-installation have been properly programmed to meet the specific requirements of the landscape and operate as intended. Common control parameters include plant types, landscape slope, and exposure. Performance parameters (Table 6-13.4) include measurement of the irrigation water volume. Water volume is to be sub-metered and measured throughout the performance period. An analysis of the metered data will be completed each year to verify generated savings.

Water use over the performance period can be normalized to typical conditions to account for seasonal variations. See the *Outdoor Irrigation Measurement and Verification Protocol* for method to normalize irrigation use.

Table 6-13.4. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Water Use of Irrigation System			
Performance/Operational	Baseline	Water use	Metered data, spot measurement, flow rate determination, or irrigation audit[48]
Performance/Operational	Post-Installation	Water use	Continuous/Short-term
Performance/Operational	Performance	Water use	Metered data

[48] See *Outdoor Irrigation Measurement Verification Protocol* for methods on baselining irrigation water use: https://www.nrel.gov/docs/fy18osti/70218.pdf

6.13.4.3 M&V Performance Assurance Activities

- Verify proper installation and performance of irrigation system.
- Inspect the system to ensure proper operation and performance including (but not limited to):[49]
    - Component leaks
    - Sprinkler head alignment and condition
    - Irrigation schedule and control settings
    - Vegetation condition and appearance
- Customer witnessing of M&V activities.

6.13.5 ECM: ALTERNATIVE WATER SYSTEMS

This measure involves installing an alternative water system to supply water to a site. Alternative water includes sustainable sources of water that are not from freshwater sources[50]. Alternative water systems collect, store, and treat water that is reused in water-consuming applications. Common applications include irrigation, toilet and urinal flushing, cooling tower makeup and vehicle wash. Alternative water can be treated to potable or non-potable levels. Components of alternative water systems include water storage, treatment, and distribution, which should be included in the performance assurance specifications of the project.

Common alternative water sources include (but are not limited to):

- **Harvested rainwater and stormwater:** precipitation from roofs (rainwater) and hardscape (stormwater)
- **Reclaimed wastewater**: wastewater treated to the level where it is suitable for reuse
- **Process water reuse**: discharge water from process water use (e.g., cooling tower blowdown, discharge from water purification system)
- **Condensate capture**: condensate collected from air handling units
- **Foundation water**: water diverted from building foundation and stored for reuse

6.13.5.1 M&V Plan Description

Option B is recommended to validate ECM performance and ongoing verification of savings during the performance period to quantify the water consumption savings, including metering the system flow rate over time.

[49] For additional details on M&V protocols for water meters, go to *Outdoor Irrigation Measurement and Verification Protocol* for method to normalize irrigation use

[50] Freshwater sources are considered surface and groundwater.

6.13.5.2 M&V Option Selection Rationale

The overall savings associated with this measure can be quantified by measuring the volume of water supplied from the alternative water source. The alternative water production is metered through a production (revenue grade) meter.

Performance parameters (Table 6-13.5) include measurement of the alternative water volume. Water volume is to be sub-metered and measured throughout the performance period.

An analysis of the metered data will be completed each year to verify generated savings.

Table 6-13.5. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Produce volume of alternative water			
Performance/Operational	Baseline	None	None
Performance/Operational	Post-Installation	Alternative water volume	Continuous/Short-term
Performance/Operational	Performance	Alternative water volume	Metered data

6.13.5.3 M&V Performance Assurance Activities

- Inspect alternative water system to ensure proper operation and maximum performance especially related to the water treatment requirements of the system to ensure the proper water quality is being supplied to the application.[51]
- Submeter the alternative water volume to verify water production and offset of freshwater.
- Customer witnessing of M&V activities.

6.14 ELECTRICAL PEAK SHAVING/LOAD SHIFTING

Measures under this technology category include improvements related to electrical peak shaving or load shifting including, but not limited to, thermal energy storage, gas cooling, battery energy storage, EMCS/BAS control strategies (e.g., schedule set-backs, pre-cooling, demand-limiting), or direct load control (from serving utilities), including “smart” appliances and equipment.

6.14.1 ECM: BATTERY ENERGY STORAGE SYSTEMS

This measure involves installing a stationary battery energy storage system (BESS) to reduce peak demand and time-of-use energy charges. Electricity is stored by the BESS and is later discharged to reduce on-peak demand and energy charges. Savings are based on reduction in power demand compared with the baseline electric load and/or based on a reduction in time-of-use charges.

[51] Find more information in the FEMP resource on operation and maintenance activities related to rainwater harvesting systems

6.14.1.1 M&V Plan Description

Option B is recommended to validate ECM performance and ongoing verification of savings during the performance period through metering of key parameters.

6.14.1.2 M&V Option Selection Rationale

The overall cost savings associated with this measure can be quantified by measuring the interval demand billing data, interval BESS charging data, and interval BESS discharging data**.** All calculations discussed below apply for all timesteps in the interval data.

The site electric load plus the additional load from charging the BESS, minus the load reductions from the BESS discharging, must all be considered in determining savings. The baseline is the site electric load prior to BESS installation, and the post-installation load is the metered site electric load after BESS installation. Demand reduction savings will be calculated by subtracting the measured peak demand of the post-installation load from the calculated peak demand of the baseline electric load. Peak demand for both the baseline load and post-installation load is defined as the average demand over the customer's highest demand billing interval (e.g., 15-minutes) within the billing period.

Time-of-use savings will be calculated as the difference between the sum of all interval BESS discharge timesteps multiplied by their corresponding time-of-use energy rate, and the summed BESS charge timesteps multiplied by their corresponding time-of-use energy rates.

Performance parameters (Table 6-11.3) include measurement and tracking of the BESS interval charge data, the BESS interval discharge data, and round-trip battery efficiency.

Table 6-11.3. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Electric interval data			
Performance/Operational	Baseline	Facility electric meters	Evaluate interval data
Performance/Operational	Post-Installation	All installed BESS	Short-term/continuous
Performance/Operational	Performance	All installed BESS	Continuous metered data

*It is recommended that Post-Installation performance verification occur over a 30-day measurement period in a month where peak demand is typically set, and continuous measurement should occur throughout the ECM lifespan.

6.14.1.3 M&V Performance Assurance Activities

- Verify installation and operation of BESS.
- Interval demand billing data and BESS charging and discharging rates will be monitored throughout the performance period. Metered data will be analyzed to verify demand reduction and round-trip efficiency.
- Customer witnessing of M&V activities.

6.14.2 ECM: THERMAL ENERGY STORAGE

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.

6.14.2.1 M&V Plan Description

Option B is recommended to validate ECM performance and ongoing verification of savings during the performance period through measurement of key parameters, to quantify the demand cost reductions associated with TES.

6.14.2.2 M&V Option Selection Rationale

The overall cost savings associated with this measure can be 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.

Table 6-14.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Thermal equipment efficiency			
Performance	Baseline	TES system	Short-term measurement
Performance	Post-Installation	TES system	Short-term measurements
Performance	Performance	TES system	Short-term measurements or from EMCS
Metered Energy Consumption			
Operational	Baseline	Cooling equipment	Short-term measurement
Operational	Post-Installation	Cooling equipment	Short-term measurements
Operational	Performance	Cooling equipment	Short-term measurements or from EMCS

6.14.2.3 M&V Performance Assurance Activities

- Verify installation and operation 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.
- Customer witnessing of M&V activities.

6.15 ENERGY COST REDUCTION THROUGH RATE ADJUSTMENTS

Measures under this technology category include improvements related to energy cost reductions through utility rate adjustments including, but not limited to, changes to more favorable rate schedule; lower energy cost supplier(s) (where applicable), or energy service billing and meter auditing recommendations.

6.15.1 ECM: DISPATCHABLE LOAD MANAGEMENT

This measure involves the use of an energy management control system (EMCS) or other dispatchable method of achieving short-term electric load reductions.

6.15.1.1 M&V Plan Description

Option C is recommended to validate ECM performance and quantify the reductions in demand or time-of-use (TOU) charges associated with the load management.

Where routine/repeated demand control is warranted (e.g., to reduce a monthly demand peak or shift daily load from a peak TOU period), check interval (15-minute, hourly) readings of facility utility meter(s) during the relevant season to determine typical day of week and time-of-day when demand peak is reached (e.g., Tuesdays, 4 to 5 P.M.) or determine from tariff when TOU peak period is in effect. Monitor interval meter readings as demand reduction routine (e.g., control sequence) is initiated to determine reduction in relevant building meter. Assess building meter trend log to measure consistency of load drop across sample of peak periods.

Where only episodic load drops (e.g., pursuant to a called demand response “events”) are the aim, monitor interval meter readings as demand reduction routine (e.g., control sequence or occupant alert) is initiated to assess reduction in relevant building meter. Check building meter trend log during a sample of called events to measure consistency of load drop.

Alternatively, use utility or ISO/RTO records of event participation to assess magnitude of load drops across relevant season or year.

6.15.1.2 M&V Option Selection Rationale

The overall cost savings associated with this measure can be quantified by measuring the interval demand billing data**.** All calculations discussed below apply for all timesteps in the interval data.

The site electric load must be considered in determining savings. The baseline is the site electric load prior to implementing dispatchable load management, and the post-installation load is the metered site electric load after implementing. Demand reduction savings will be calculated by subtracting the measured peak demand of the post-installation load from the calculated peak demand of the baseline electric load. Peak demand for both the baseline load and post-installation load is defined as the average demand over the customer’s highest demand billing interval (e.g., 15-minutes) within the billing period.

Time-of-use savings will be calculated as the difference between the sum of all interval dispatched load management timesteps multiplied by their corresponding time-of-use energy rate.

Performance parameters (Table 6-11.3) include measurement and tracking of the load management data.

Table 6-15.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Reduced Kilowatts			

Performance/Operational	Baseline	Facility electric meters	Evaluate interval data
Performance/Operational	Post-Installation	Facility electric meters	Evaluate interval data
Performance/Operational	Performance	Facility electric meters	Evaluate interval data

6.15.1.3 M&V Performance Assurance Activities

- Interval demand billing data will be monitored throughout the performance period.
- Metered data will be analyzed to verify the guaranteed savings.
- Savings are based on reduction in power demand compared with the counterfactual load and/or based on a reduction in time-of-use charges.
- Customer witnessing of M&V activities.

6.16 ENERGY RELATED PROCESS IMPROVEMENTS

Measures under this technology category include improvements associated with energy related process improvements including, but not limited to, production and/or manufacturing improvements, recycling and other waste stream reductions, or industrial process improvements.

6.16.1 ECM: AIR COMPRESSOR AND VACUUM PUMP IMPROVEMENTS

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 is recommended to validate ECM performance and ongoing verification of savings during the performance period to quantify the energy consumption savings associated with improved compressor/vacuum controls, system upgrades, and efficiency.

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.

Performance parameters (Table 6-16) include short-term data logging of the compressor power draw (kW) 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, post-installation, 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 runtime will also be collected during baseline development, post-installation, and throughout the life of the contract. This will demonstrate the reduced runtime with system upgrades and improved controls.

Table 6-16.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Compressor/Vacuum Pump Kilowatts			
Performance	Baseline	All compressors/vacuum pumps above 20 hp	Short-term measurement
Performance	Post-Installation	All compressors/vacuum pumps above 20 hp	Short-term measurement
Performance	Performance	All compressors/vacuum pumps above 20 hp	Short-term measurement
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
Runtime			
Operational	Baseline	All compressors/vacuum pumps above 20 hp	Short-term measurement
Operational	Post-Installation	All compressors/vacuum pumps above 20 hp	Short-term measurement
Operational	Performance	All compressors/vacuum pumps above 20 hp	Short-term measurement

6.16.1.3 M&V Performance Assurance Activities

- Verify installation of upgraded compressor/vacuum, improved controls, and improved system upgrades.
- Perform measurements on power draw (kW) 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.
- Customer witnessing of M&V activities.

6.16.2 ECM: GRID-INTERACTIVE EFFICIENT BUILDING (GEB)

Grid-Interactive Efficient Buildings (GEBs) work to remake buildings into clean and flexible energy resources by combining energy efficiency and demand flexibility with smart technologies and communications. It is an effective initiative to inexpensively deliver greater affordability, comfort, productivity, and performance to buildings. Advanced controls enable buildings to adjust power consumption to meet grid needs through a variety of control strategies applied to existing equipment, such as lighting and heating, ventilating, and air conditioning (HVAC), along with on-site assets like solar photovoltaics (PV), and electrical and thermal storage.

Energy demand and cost savings from GEBs typically result from the use of advanced control strategies to promote communication between the building, grid, and building technologies that change the way a building consumes energy to avoid high peak load costs or to make building operations more resilient.[52] These strategies may include reducing energy use in peak times,

[52] Matt Jungclaus, Cara Carmichael, and Phil Keuhn, Value Potential for Grid-Interactive Efficient Buildings in the GSA Portfolio: A Cost-Benefit Analysis, Rocky Mountain Institute, 2019. http://www.rmi.org/GEBs_report

shifting energy to another time period based on demand, adjusting the power draw, or even increasing energy consumption to store (e.g., battery or thermal energy storage) for later use when demand rises. What makes GEB different from other building automation or energy management control systems is this interaction with the grid to realize savings.

6.16.2.1 M&V Plan Description

Option B is recommended to validate ECM performance during the performance period through continuous measurement of key parameters. This will ensure that the ECMs are operating properly while maintaining occupant needs and comfort. Option B was chosen to ensure systems are performing as expected.[53,54]

A calibrated simulation is recommended to quantify the energy use and demand reductions generated by desired setpoints and is chosen when GEB controls are implemented. By utilizing a calibrated model, the estimated effects of ECM interactivity within the building and its impact on energy and demand savings can be determined.[55]

6.16.2.2 M&V Option Selection Rationale

Savings are the result of reduced energy consumption and demand charges of a facility. Demand rates can be calculated in one of a few ways, through negotiated rates, fixed fee, or a hybrid rate method where the customer pays a fixed fee if demand levels are below a certain threshold. To realize the most savings from a GEB, it is best to consult with the site utility to ensure that demand is calculated using negotiated rates.

Savings will vary based on parameters, setpoints, the performance of the utility grid, working controls, etc. Due to the multiple interactions caused by equipment, setpoints, and the grid, it is recommended to utilize an energy analysis model to analyze energy savings and peak demand. Weather data must be leveraged for pre-retrofit and post-retrofit building models.

HVAC systems tend to be a driver for peak demand energy usage as these systems consume a significant amount of energy specifically in peak times. Monitoring the energy usage of these systems can ensure that the components are operating efficiently while verifying the system is properly communicating with the GEB control system.

If the facility is using a dual-fuel HVAC system, where one or more of the fuels are provided through a utility, monitoring when and how long each fuel is used is necessary for the long-term performance of the system and the verification of the savings.

The performance parameters (Table 6-16.2) shown, including setpoints, HVAC usage, and total building energy usage can be utilized to ensure that both new and existing systems are running

[53] International Performance Measurement & Verification Protocol Committee. (2002). International Performance Measurement & Verification Protocol: Concepts and Options for Determining Energy and Water Savings. Oak Ridge, TN: U.S. Department of Energy.
[54] International Performance Measurement & Verification Protocol Committee. (2022). International Performance Measurement & Verification Protocol: Core Concepts. Washington D.C.: Efficiency Valuation Organization.
[55] ASHRAE Guideline 14-2014: Measurement of Energy, Demand and Water Savings, American Society of Heating, Refrigerating, and Air Conditioning Engineers.

when needed, as needed, and are working properly. Increases in energy consumption or changes in setpoints may be a sign of possible problems or mission changes. These will need to be addressed as early as possible to ensure savings are maintained.

As GEBs strive to reduce the energy consumption of the building as well as to lower demand costs, ECMs that can shift demand or shave energy usage are important. Some ECMs, such as integrated batteries in lighting ballasts, may also be leveraged to boost other site performance factors, such as site resilience.

Some of the most common operational and performance parameters for GEBs are found in Table 6-16.2 below. Other operational and performance factors include integrated batteries in lighting ballasts, advanced lighting control systems, solid-sate lighting displays, energy management system-maintained grid-interaction, advanced controls for commercial refrigeration, and HVAC control (rule-based).

Table 6-16.2. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Measurement
Space Set Point Factors (e.g., building usage, occupancy levels, space changes)			
Performance	Baseline	Whole Building	Short-term metering
Performance	Post-Installation	Whole Building	Trending of EMCS logs and reports from site operations staff
Performance	Performance	Whole Building	Trending of EMCS logs and reports from site operations staff
HVAC Energy Usage			
Performance	Baseline	All HVAC Systems	Short-term metering
Performance	Post-Installation	All HVAC Systems	Trending of EMCS logs
Performance	Performance	All HVAC Systems	Trending of EMCS logs
Whole Building Electricity Usage			
Performance	Baseline	All Spaces	Short-Term metering
Performance	Post-Installation	All Spaces	Short-Term metering
Performance	Performance	All Spaces	Short-Term metering
Lighting Energy Usage			
Performance	Baseline	All Lighting Systems	Short-term metering
Performance	Post-Installation	All Lighting Systems	Short-term metering
Performance	Performance	All Lighting Systems	Short-term metering
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

6.16.2.3 M&V Performance Assurance Activities

- Verify Installation of new equipment and controls
- Ensure utility charges for demand rates is based on demand usage and is not a flat rate.
- Verify energy savings and demand savings through power measurements and simulations.
- Ensure occupant comfort is maintained and remains uncompromised due to GEB controls and setpoints.

- Obtain customer approval of all performance and operational parameters shown in the baseline and post-installation parameter value tables.
- Customer witnessing of M&V activities.

6.17 COMMISSIONING

Measures under this technology category include improvements related to commissioning buildings, systems and equipment including, but not limited to, retro-commissioning or re-commissioning; ongoing/continuous commissioning services; or monitoring-based commissioning.

6.17.1 ECM: RETROCOMMISSIONING/RECOMMISSIONING

This ECM involves a re-commissioning or retro-commissioning of energy-using systems or whole buildings. *Re*-commissioning applies to equipment that was previously commissioned, while *retro*-commissioning applies to equipment that was never commissioned. Both can be abbreviated as RCx. They typically include the savings associated with repair or extension of, and upgrades to, the existing operating controls at the facility.

6.17.1.1 M&V Plan Description

Option A will be used to validate ECM performance during the performance period through continuous measurement of selected key parameters. A calibrated model is recommended to estimate energy savings associated with RCx through the first year of performance 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 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 that can be evaluated to estimate the savings from RCx measures. The baseline model is calibrated to utility bills or short-term metered data.

Performance parameters (Table 6-17.1) include space set points, airflow, and supply temperatures. RCx improves the performance of existing equipment. The performance parameters selected will be those that generate the most savings or have the greatest impact on savings. It is recommended that performance parameters be verified through an EMCS during the performance period.

The only operational parameter is equipment runtime. It is recommended to perform short-term data logging during the baseline development and use the EMCS system during post-installation and the performance period to validate performance. Equipment that will have the largest effect on savings should be metered (Table 6-17.1).

The model will ultimately predict energy savings. During ECM development, the model will serve to establish the baseline and predict the post-retrofit energy consumption based on the ECM's effects within the model. The energy model will be calibrated with past utility data and spot measurements in order to develop an acceptable baseline representation. The recorded data will be used as inputs to the model.

Table 6-17.1. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Space Set points			
Performance	Baseline	All spaces	Short-term measurements
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 measurements
Performance	Post-Installation	All AHUs	Trending of EMCS logs
Performance	Performance	All AHUs	Trending of EMCS logs
Equipment Runtime			
Operation	Baseline	Key equipment	Short-term measurements
Operation	Post-Installation	Key equipment	Trending of EMCS logs
Operation	Performance	Key equipment	Trending of EMCS logs

6.17.1.3 M&V Performance Assurance Activities

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

6.17.2 ECM: MONITORING-BASED COMMISSIONING

Monitoring-based commissioning (MBCx) is the continuous application of the commissioning process to a building or energy system. It is an effective method to keep energy costs low and minimize system problems that may be caused over time by building performance deterioration and changes to building operations (Swegon Air Academy 2017). MBCx is implemented via software tools that compile and analyze real-time building energy system data, identify performance issues through automated fault detection and diagnostics, assist with equipment commissioning, and optimize system operations.

Energy and cost savings from MBCx typically result from optimizing EMCS control sequences and repairing, replacing, or recommissioning any malfunctioning HVAC components and other equipment identified by the MBCx process. Additional savings may also occur from optimizing operation of lighting or plug load controls that are connected to the MBCx, for example.

6.17.2.1 M&V Plan Description

Option B is recommended to validate ECM performance during the performance period through continuous measurement of key parameters. A calibrated simulation is recommended to estimate energy savings associated with MBCx due to the interactions between affected energy consuming equipment and HVAC equipment when MBCx processes are implemented.

6.17.2.2 M&V Option Selection Rationale

MBCx provides a source of 15-minute data and therefore will be used for M&V activities with this ECM. Option B is recommended for ongoing verification of the performance of this ECM. Under this strategy, ongoing performance measurements [e.g., air handling unit (AHU) runtime, reset schedules] are collected through the MBCx software. It is recommended that the MBCx dashboard be set up to continuously validate ECM performance on a 15-minute basis.

Performance parameters of identified HVAC equipment (Table 6-17.2) will be short-term data logged during the baseline and post-installation periods. The performance parameters will be collected by the MBCx trending data during the performance period. In addition, energy and cost data will be collected through the advanced metering infrastructure (AMI). This could reduce M&V costs.

Operational parameters (temperature set points, setbacks, reset schedules, runtimes, 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 6-17.2).

Post-installation, operation of MBCx will be verified during the commissioning process to ensure functionality.

The calibrated computer simulation model will ultimately predict energy savings. During ECM development, the model will serve to establish the baseline and predict the post-retrofit energy consumption based on the ECM's effects within the model. The model will be calibrated with past utility data and spot measurements ensure baselined- and post- representation. The recorded data will be used as inputs to the model.

Table 6-17.2. M&V Plan Performance and Operational Parameters

Parameter	Period	Population	Activity
Equipment (HVAC, Lighting, Plug Loads Power) Power (kW)			
Performance	Baseline	Key equipment	Short-term measurement
Performance	Post-Installation	Key equipment	From EMCS or AMI
Performance	Performance	Key equipment	From EMCS or AMI
Space Set points, Setbacks (°F)			
Operational	Baseline	All spaces	Short-term measurement
Operational	Post-Installation	All spaces	From EMCS
Operational	Performance	All spaces	From EMCS
Airflows (CFM) and Supply Temperatures (°F)			
Operational	Baseline	All AHUs	Short-term measurement
Operational	Post-Installation	All AHUs	From EMCS
Operational	Performance	All AHUs	From EMCS

Equipment (HVAC, Lighting, Plug Loads) Runtime (hours)			
Operational	Baseline	Key equipment	Short-term measurement
Operational	Post-Installation	Key equipment	From EMCS
Operational	Performance	Key equipment	From EMCS

6.17.2.3 M&V Performance Assurance Activities

- Verify installation of applicable MBCx software and hardware, and that the MBCx software is properly commissioned.
- Verify equipment and parameters monitored by MBCx.
- Verify that ECMs identified by the MBCx are implemented and achieving desired savings.
- Ensure that responsibilities for updating automated reporting and creating periodic reports via the MBCx software tool to support project M&V requirements are carried out (this could be by the ESCO, the subcontractor implementing MBCx software, or the site BAS staff).
- Quarterly review of automated MBCx M&V reports 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 and implementing ECMs identified by the MBCx platform.
- Customer witnessing of M&V activities.

APPENDIX A. GLOSSARY

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.

Table A-1. Definition of Terms

TERM	DEFINITION
Adjustments, Routine	Changes made to account for variations in independent variables within the measurement boundary that affect the baseline and/or the performance period energy/water use like weather (outside air temperature).
Adjustments, Non-routine	Changes made to the baseline and/or the performance period energy/water use due to unexpected changes to static factors within the measurement boundary.
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 contractor's (ESCO) invoice after the regular interval report has been reviewed and approved by the customer.
Avoided Energy (or water) Use	The reductions in energy (or water) 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 (or water) 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 (or water) savings measures (such as equipment inventory and conditions, occupancy, nameplate data, energy or water 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 or water use.
Baseline Energy, Water or Demand	The calculated or measured energy or water use or demand by a piece of equipment or a site before implementation of the project.
Commissioning	Procedures undertaken, generally by the contractor, to assure that ECMs/WCMs and building systems perform interactively in accordance with design documentation and intent. An independent party may complete system/equipment commissioning. The latest FEMP Commissioning Guidance for ESPCs provides the key elements of commissioning as it relates to federal ESPCs. Cx activities may be based on technical guidelines such as American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Guideline 0-2019, *The Commissioning Process*.

TERM	DEFINITION
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, retrofit activities, or energy consuming devices and required support structures. *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 Savings Performance Contract (ESPC)	A firm-fixed-price contract meeting the statutory requirements of 42 U.S.C. §§ 8287, et seq., to achieving energy and/or water savings, which provides the performance of services for the design, acquisition, installation, testing, measurement and verification, and, where appropriate, operation, maintenance, repair or replacement, of identified energy conservation measures at one or more locations with no up-front capital costs or appropriations and a term not to exceed 25 years. Under an ESPC, the contractor must provide a performance guarantee (including guaranteed annual energy and/or water cost savings) to the Federal agency.
Energy Services Company (ESCO)	An organization that designs, finances, procures, installs, and possibly maintains one or more ECMs/WCMs or systems at a facility or facilities, typically under a performance contract or task order.
Estimated Savings	Estimated savings are those determined during project development and specified in the contract before project implementation and determined from M&V activities and/or calculations described in the project-specific M&V plan. The Contractor may not guarantee 100% of estimated savings.
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.
Guaranteed Savings	Guaranteed (cost) savings are the levels of cost savings assured by the contractor to be realized by the customer in each year of the contract and may be energy, water, energy-related, water-related cost savings, both recurring and non-recurring. Guaranteed cost savings are verified on an annual basis through M&V activities outlined in the M&V plan and documented in the M&V report.
Independent Variable	A parameter that is expected to change and may have a measurable effect on the energy consumption or water use of a building or system, such as weather.
Insolation	A measure of solar radiation energy received on a given surface area in a given time.
Interactive Effects	Energy (or water) consumption changes to one system resulting from changes made to another building system.
Investment Grade Audit (IGA)	A site survey / energy audit of a potential project site's baseline energy/water conditions and potential ECMs/WCMs, with a detailed analysis of the ECMs'/WCMs' and the site's energy/water cost savings and energy/water unit savings potential, for the purpose of preparing technical and price proposals. Also may be referred to as a detailed feasibility study.
Measurement and Verification (M&V) Approach	An evaluation procedure for determining energy, water, and related 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 performance-based contracting 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 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.

TERM	DEFINITION
Measurements, Spot	Measurements taken one time; snap-shot measurements.
Monitoring-based Commissioning (MBCx)	The continuous application of the commissioning process to a building or energy system.
Normalized Savings	The reductions in energy (or water) 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 meet performance requirements and deliver the guaranteed or assured 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 (or Water) Use or Demand	The calculated energy (or water) 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 the 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	A feasibility study/energy audit (i.e. high-level assessment) which may include, but is not limited to, an evaluation of energy/water cost savings and energy unit savings potential, building conditions, energy consuming (or water using) equipment, and hours of use or occupancy.
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.
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.
Static Factor	Those characteristics of a facility which affect energy consumption or water use within the defined measurement boundary that are not expected to change, such as facility occupancy and operating hours, and equipment loads, run times, and operational conditions.
Typical Meteorological Year (TMY)	Collection of select weather data with hourly values that represent the median weather conditions for a specific location for a typical year, derived from a multi-year period. TMY datasets are used in projecting energy usage over the contract term, representing typical conditions and normalized weather data.
Usage Group	A collection of equipment (e.g., motors or rooms with light fixtures) with similar characteristics (e.g., operating schedule).
Utility Energy Service Contract (UESC)	A limited-source acquisition between a federal agency and their distribution utility for energy management services including demand reduction, and energy and water efficiency improvements.
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 following the -specific M&V plan, 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 M&V submittals required in each phase of federal 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 M&V savings terminology used specifically in federal ESPC projects, by phase, is presented in Table B-2. Note that the term "guaranteed savings" is used throughout project development, project acceptance and performance period phases and in M&V submittals.

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, Responsibility, and Performance 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
Post-Installation Summary Findings[b]	Electronically through eProject Builder as available and in Post-Installation Report	Before project acceptance
Annual M&V Reports	Separate submittal	30 days after anniversary date of project acceptance, depending on task order terms.
Annual Report Summary Findings[b]	Electronically through eProject Builder as available and in Annual M&V Report	30 days after anniversary date of project acceptance, depending on task order terms.

[a]Detailed information on the US Department of Energy ESPC process is available at https://www.energy.gov/femp/process-procuring-federal-energy-savings-performance-contract

[b]Required of projects under DOE ESPC IDIQ contract

Table B-2. Energy Savings Performance Contract Project Savings Terminology by Phase

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

B.1 M&V APPROACH

The first M&V-related item received for a federal ESPC project is the ECM/WCM performance measurement section of the preliminary assessment. This section provides a general description of the M&V plan for the project and addresses the proposed baseline development approach and how government witnessing will be addressed, including sample witnessing forms. 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, RESPONSIBILITY, AND PERFORMANCE MATRIX

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

The RRP 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 various risks.

The RRP matrix indicates the responsibility and performance of actions agreed to by the ESCO and the Government. The final agreed-upon RRP 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/WCM, 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
- Level of government witnessing for each ECM/WCM
- Witnessing activities for each ECM/WCM (e.g., measurements, inspections)
- 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.[56]

B.4 COMMISSIONING APPROACH, PLAN, AND REPORT

The commissioning approach for each ECM/WCM is included as a severable document in the ECM/WCM 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/WCM with specific steps that will be taken during the commissioning process.

Once ECM/WCM commissioning activities have been completed and facility performance requirements documented per the approved commissioning plan and ordering agency requirements, the commissioning report is submitted by the Contractor before project acceptance. This report details the inspections and performance tests performed, along with the results of these inspections and tests, to ensure that the systems were installed and perform properly. It also verifies systems and equipment are operating according to design intent.

For commissioning guidance for ESPCs, refer to FEMP's guidance ("Commissioning Guidance for ESPCs"), available on DOE FEMP's website under "Resources for Implementing Federal Energy Savings Performance Contracts" at https://www.energy.gov/femp/resources-implementing-federal-energy-savings-performance-contracts.

B.5 POST-INSTALLATION REPORT

After the commissioning activities have been completed and the 30-day proof of performance (if applicable), the post-installation verification activities defined in the M&V plan are conducted. The federal agency witnesses the inspections and measurements conducted by the Contractor.

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 includes the expected savings for the project. The federal agency provides written acceptance of, and/or review comments on, the post-installation report. The Contractor replies to any post-installation report comments.

The post-installation report includes results of the eProject Builder (ePB) output,[57] M&V data and calculations. 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.

[56] The M&V Plan outline as found in Appendix C is required for use in federal ESPC contracts utilizing the DOE ESPC IDIQ contract.
[57] See Attachment J-8 of the 2023 (Gen 4) DOE ESPC IDIQ contract.

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 one year 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 (verification, measurements, savings calculations) and reports the verified annual energy and cost savings. The report also describes operations, preventive maintenance, and repair and/or replacement 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 cost savings guarantee for the overall project has been met and not that the predicted savings for each ECM/WCM have been achieved. The federal agency witnesses verification activities (e.g., inspections, measurements) conducted by the Contractor during the annual inspection as described in the M&V plan. In some instances, the federal agency may conduct M&V activities, as described in the M&V plan.

Each annual M&V report includes a section that documents, on a continuous basis, any changes or impacts that have affected the ability of the project to generate energy and water savings. This "running log of impacts" with associated impact on energy and water savings, is included to inform whether a task order adjustment may be necessary.

The verified savings values presented in the annual M&V 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 M&V 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.

The annual M&V report includes the results of the eProject Builder (ePB) output, data and calculations used to demonstrate that continued ECM/WCM performance achieves the guaranteed annual cost savings as required by the task order. Additionally, each annual M&V report includes a copy of the previous year's M&V report comments and responses in an appendix to the report, for the purpose of bringing consistency to the M&V evaluation process.

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

B.7 CRITERIA FOR ENERGY AND WATER 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, retrofit activities, or energy consuming devices and required support structures . See 42 U.S.C. § 8259(4) and 10 CFR part 436. 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 10 CFR part 436, subpart A, either using an approach that views individual ECMs/WCMs in isolation or in the context of all contemplated ECMs/WCMs, and for one or more federal buildings, under the same project. Thus, evaluating life cycle cost-effectiveness using a federal building-wide approach may account for the relationship of multiple ECMs/WCMs 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).

APPENDIX C. ESPC M&V PLAN OUTLINE

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 Estimated Savings Calculations

1.1 Estimated Annual Savings Overview

Table C-1. Estimated Annual Savings Overview

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

ECM / WCM	Total energy savings (MMBtu/ year)**	Electric energy savings (kWh/ year)	Electric demand savings (kW/ year)*	Natural gas savings (MMBtu/ year)**	Water savings (kGal/ year)	Other energy savings (MMBtu/ 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: MMBtu = 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 MMBtu, note the other energy savings type and provide a conversion factor to MMBtu for link to Task Order schedules (e.g., 0.003413 MMBtu/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 (MMBtu/year)	Total Greenhouse Gas emissions (MT CO2e/year)*	Electric energy (kWh/year)	Electric demand (kW/year)**	Natural gas (MMBtu/year)	Water (kGal/year)	Other energy (MMBtu/year) ***
Total estimated project savings							
Usage for entire site****							
% Total site usage saved							
Project square footage (KSF)							
Total site square footage (KSF)							
% Total site area affected							

Notes:

MMBtu = 10^6 Btu
KSF = 10^3 square feet.
* Describe factor(s) used in determining GHG emission reductions (e.g., eGRID sub-region, year for electric emission factors).
**Annual electric demand savings (kW/year) is the sum of the monthly demand savings.
***If energy is reported in units other than MMBtu, note other energy type and provide a conversion factor to MMBtu for link to Task Order schedules (e.g., 0.003413 MMBtu/kWh).
****Define usage period.

1.1.2 M&V Plan Summary

Specify the M&V Options and Methods for Each ECM/WCM

Table C-2. M&V Plan Summary

ECM / WCM No.	ECM/WCM Description	M&V Option Used*	Summary of M&V Plan Requirements, Performance Year M&V Activities

*M&V options A, B, C, and D; methods proposed for each ECM/WCM shall comply with the latest version of the "DOE/FEMP M&V Guidelines: Measurement and Verification for Performance-Based Projects."

2. Whole Project Data/Global Assumptions

2.1 Risk, Responsibility, and Performance

- Summarize approach to M&V options, including baseline development, post-installation verification activities and performance period verification activities
- Summarize allocation of responsibility for key items related to M&V
- Reference the location of the completed RRP Matrix

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

2.2.1 Detail baseline energy and water rates.

2.2.2 Provide post-acceptance performance period rate adjustment factors (i.e., escalation rates) for energy, water, and O&M cost savings, if used.

2.3 Schedule & Reporting for Verification Activities

2.3.1 Define schedule of M&V activities, requirements for and recommended level of government witnessing for M&V activities for each ECM/WCM during:

- Baseline development
- Post-installation verification activities
- Post-acceptance performance period

2.3.2 Define schedule of verification reporting activities (Table C-3).

Table C-3. Schedule of Verification Reporting Activities

Item	[a] Recommended Time of Submission	[a] Ordering Agency's Review and Written Acceptance Period
Post-Installation Report	30 days after implementation period and prior to Government acceptance	20 working days
Annual M&V Report	30 days after annual performance period	20 working days

[a]Times are based on 2023 (Gen 4) DOE ESPC IDIQ contract; modify as needed.

2.3.3 Define content and format of reports:

- Post-installation report. See Appendix D.
- Annual M&V reports. See Appendix E.
- Interval M&V reports. Develop report outline if needed.

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

2.4.1 Define Government and ESCO reporting requirements.

- Summarize key verification and Government witnessing activities and reporting responsibilities of Government and ESCO on operations, preventive maintenance, repair, and replacement items from details in ECM/WCM-specific M&V plans.
- Define content of reports and reporting schedule.
- Specify corrective actions in the event deficiencies in operations, preventive maintenance, repair and/or replacement activities are found.

2.5 Construction/Project Implementation Period Savings

2.5.1 Provide overview of how construction/project implementation period savings will be calculated and verified, if applicable.

2.6 Status of Financial Incentives, including Rebates

Include if applicable.

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

2.6.2 Provide status of any third-party rebates, grants 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/WCM-Specific M&V Plan and Savings Calculation Methods

- Develop section for each ECM/WCM.

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

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 version of FEMP M&V guideline and M&V option used

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

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

3.1.4 Provide an overview of savings calculations methods for ECM/WCM.

- 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/WCM 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 (e.g., measurements, monitoring, assumptions, manufacturer data, maintenance logs, engineering resources).

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 activities 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:

- Parameters monitored/measured
- Details of equipment monitored (e.g., location, type, model, quantity)

- Sampling plan, including details of usage groups and sample sizes
- Duration, frequency, interval, and seasonal or other requirements of measurements
- Requirements to bring current equipment up to code standards
- Personnel, dates, and times of measurements
- Proof of Government witnessing of measurements
- 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 forms as necessary)
- Completed data collection forms, if used

3.2.6 Provide details of baseline data analysis performed, including:

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

3.3 Estimated Energy and Water Savings Calculations and Methodology

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 Include 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 (escalation rates) if different from Section 2.2 of this appendix.

3.3.6 Detail estimated annual savings for this ECM/WCM for post-acceptance performance period.

- Summarize information in Table C-4 in Section 3.5 of this appendix.

3.4 Operations and Maintenance and Other Cost Savings

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

- Describe how savings are generated.
- Detail cost savings calculations including the O&M baseline.
- Provide performance period adjustment factors if different from Section 2.2 of this appendix.

3.5 Estimated Annual Savings for ECM / WCM

Table C-4. Estimated Annual Savings for Each ECM/WCM

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

	Total energy use (MMBtu/ 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 (MMBtu /year)**	Natural gas cost, Year 1 ($/year)	Water use (kGal/ year)	Water cost, Year 1 ($/year)	Other energy use (MMBtu/ year)**	Other energy cost, Year 1 ($/year)	Other energy-related O&M costs, Year 1 ($/year)	Total costs, Year 1 ($/year)	Total GHG Emission Reductions (kg CO_2e)***
Baseline use														
Post-installation use														
Savings														

Notes: MMBtu = 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 MMBtu, provide other energy type and a conversion factor to MMBtu for link to Task Order schedules (e.g., 0.003413 MMBtu/kWh).

***Describe factor(s) used in determining GHG emission reductions (e.g., eGRID sub-region and data year electric emission factors).

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 (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 Provide details of post-installation data to be collected, including:

- 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)

3.6.5 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 (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 how performance will be verified.

- Provide detailed schedule, frequency of performance period verification activities and inspections.
- Define requirements for Government witnessing of measurements if different than whole project data requirements included in section 2.3 of this appendix.

3.7.4 Provide details of performance period data to be collected, including:

- 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)

3.7.5 Detail data analysis to be performed.

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

- Detail verification activities, witnessing activities and reporting activities of the Government and ESCO on operations, preventive maintenance, repair, and replacement items.
- Define contents of report and reporting schedule, if different than section 2.4 of this appendix.

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 # / Task Order # / 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:

- Dates of relevant contract and task order modifications
- Project acceptance date (actual or expected)

1.2 Brief Project and ECM/WCM Descriptions

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

1.2.2 Note any changes in project scope between the awarded Task Order (including any relevant contract / task order modifications) and as-built conditions.

1.2.3 Summarize ECM/WCM Commissioning Dates and Date(s) of ECM/WCM Acceptance

Table D-0. ECM/WCM Commissioning Date and Date of Acceptance

ECM Number	ECM Name	ECM Location	Date ECM/WCM Commissioned	Date ECM/WCM Accepted

1.3 Estimated and Expected Energy/Water and Cost Savings for Year 1 of the Post-Acceptance **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 predicted for the first year based on post-installation M&V activities. Verified savings for the first year of the performance period will be documented in the Year One annual report. The estimated savings for each ECM/WCM are included in TO Schedule 4 of the Task Order.

Table D-1. Estimated Annual Savings Overview

[Include all applicable fuels/commodities for project, such as electric energy, electric demand, natural gas, fuel oil, coal, water, etc. using Year 1 utility rates.]

ECM / WCM	Total energy savings (MMBtu/year) **	Electric energy savings (kWh/year)	Electric demand savings (kW/year)*	Natural gas savings (MMBtu/year) **	Water savings (kGal/year)	Other energy savings (MMBtu/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 GHG Emission Reductions (kg CO_2e) ***
Total savings										
First year guaranteed savings: $****										

Notes: MMBtu = 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 MMBtu, provide other energy savings type and a conversion factor to MMBtu for link to Task Order schedules (e.g., 0.003413 MMBtu/kWh).
***Describe factor(s) used in determining GHG emission reductions (e.g., eGRID sub-region and data year electric emission factors).
****Guaranteed cost savings for project are defined in TO Schedule1 in the Task Order. The estimated savings for each ECM/WCM are included in TO Schedule 4 of the Task Order.

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

[Include all applicable fuels/commodities for project, such as electric energy, electric demand, natural gas, fuel oil, coal, water, etc. using Year 1 utility rates.]

ECM / WCM	Total energy savings (MMBtu/year)**	Electric energy savings (kWh/year)	Electric demand savings (kW/year)*	Natural gas savings (MMBtu/year)**	Water savings (kGal/year)	Other energy savings (MMBtu/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 GHG Emission Reductions (kg CO_2e)***
Total savings										

Notes: MMBtu = 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 MMBtu, provide other energy savings type and a conversion factor to MMBtu for link to Task Order schedules (e.g., 0.003413 MMBtu/kWh).
***Describe factor(s) used in determining GHG emission reductions (e.g., eGRID sub-region and data year electric emission factors).

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 post-acceptance 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 a summary of any energy and/or cost savings adjustments required between awarded TO (including any relevant contract/task order modifications) and as-built conditions.

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

1.6 Pre-Performance Period Savings

1.6.1 Provide an overview of how pre-performance period savings were calculated and verified.

1.6.2 Provide a summary of pre-performance period savings, if applicable, in Table D-2A.

Table D-2A. Summary and Status of Pre-Performance Period Savings

Pre-Performance Period Savings Type*	Source of Savings	ECM/WCM Number or Project Impacted	Estimated Amount of Savings ($)	Status of Savings (e.g., submitted, pending, received)

Notes:
* Pre-performance period savings types include grants (including AFFECT), rebates, incentives, one-time O&M cost savings (energy-/water-related cost savings), and implementation/construction period savings.

1.7 eProject Builder Output

- Include the results of eProject Builder output (performance Year 0). Use appendix and electronic format (PDF) as necessary.

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

Develop section for each ECM/WCM.

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

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 Summarize M&V Plan

- State the FEMP M&V Guidelines version and option used.
- Provide an overview of M&V activities for ECM/WCM. Explain the intent of M&V plan, including what is being verified.

2.1.3 Provide an overview of savings calculation methods for ECM/WCM. Provide a general description of analysis methods used for savings calculations.

2.2 Installation Verification

2.2.1 Detail any changes between awarded TO (including any relevant contract/task order modifications) and as-built conditions.

2.2.2 Provide details of energy and cost savings impact from changes between awarded TO (including any relevant contract / task order modifications) and as-built conditions based on post-installation M&V results.

- Include completed Table D-3.

2.2.3 Describe project implementation / construction period savings (if applicable).

- Include date ECM/WCM was in effect and reference acceptance documentation.

2.2.4 Detail savings calculations for project implementation / construction period savings.

2.3 Post-Installation M&V Activities Conducted

2.3.1 Detail measurements, monitoring, witnessing and inspections conducted in accordance with M&V plan (include all that apply for each ECM/WCM):

- Measurement equipment used.
- Equipment calibration documentation.
- Dates/times of data collection, inspections or measurements, names of personnel, and documentation of Government witnessing.
- Details to confirm adherence to sampling plan.
- 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.).
- Describe how performance criteria have been met.
- Detail any performance deficiencies that need to be addressed by the contractor (ESCO) or the Government (ordering agency).
- Note impact of performance deficiencies or enhancements on generation of savings.

Table D-3. Differences in energy, water and from changes between final proposal and as-built conditions for ECMs / WCMs

	Total energy savings (MMBtu/ 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 (MMBtu/ year)**	Natural gas cost savings, Year 1 ($/year)	Water savings (kGal/year)	Water cost savings, Year 1 ($/year)	Other energy savings (MMBtu/ year)**	Other energy cost savings, Year 1 ($/year)	Other energy-related O&M cost savings, Year 1 ($/year)	Total cost savings, Year 1 ($/year)
Estimated													
Expected													
Variance													

Notes

MMBtu = 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 MMBtu, note energy type and provide a conversion factor to MMBtu for link to task order schedules (e.g., 0.003413 MMBtu/kWh).
Note: Expected savings are predicted for the first year based on post-installation M&V activities. Verified savings for the first year of the performance period will be documented in the Year One annual report. The estimated savings for each ECM/WCM are included in TO Schedule 4 of the Task 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.
- Detail all assumptions and sources of data, including all stipulated values used in calculations.
- Include equations and technical details of all calculations made. (Use appendix and electronic format as necessary.) Include description of data format (headings, units, etc.).
- Include details of any baseline changes or savings adjustments made.
- Detail energy and water rates used to calculate cost savings (if different from section 1.4 of this appendix).
  - Provide post-acceptance performance period energy and water rate adjustment factors, if used.
  - Report actual energy and water rates at site for same period (optional).
- Detail expected savings for energy conservation measure for the first year. Include completed Table D-4.

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

2.5.1 Describe source of savings, if applicable.

2.5.2 Describe verification activities.

2.5.3 Provide performance period adjustment factors, if applicable.

Table D-4. Expected Year 1 Savings for ECM / WCM

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

	Total energy use (MMBtu/ year)**	Electric energy use (kWh/ year)	Electric energy cost ($/year)	Electric demand (kW/year)*	Electric demand cost ($/year)	Natural gas use (MMBtu/ year)**	Natural gas cost ($/year)	Water use (kGal/year)	Water cost ($/year)	Other energy use (MMBtu/ year)**	Other energy cost ($/year)	Other energy-related O&M costs ($/year)	Total costs ($/year)	Total GHG Emission Reductions (kg CO_2e)***
Baseline use														
Post-installation use														
Savings														

Notes

MMBtu = 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 MMBtu, note energy type and provide a conversion factor to MMBtu for link to task order schedules (e.g., 0.003413 MMBtu/kWh).
***Describe factor(s) used in determining GHG emission reductions (e.g., eGRID sub-region, year for electric emission factors).

APPENDIX E. ESPC ANNUAL M&V REPORT OUTLINE

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

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

Performance Period Dates Covered: _______to_______

Contract year #: _______ of ________

1. Executive Summary

1.1 Project Background

1.1.1 Provide an overview of project background, including:

- Dates and descriptions of relevant contract / task order modifications
- Project acceptance date

1.2 Brief Project and ECM / WCM Descriptions

1.2.1 Provide an overview including M&V activities performed and how savings are generated.

1.2.2 Summarize the original M&V plan requirements and performance year M&V activities by including Appendix C Section 1.2 Table C-2 "M&V Plan Summary".

Table C-2. M&V Plan Summary

ECM / WCM No.	ECM/WCM Description	M&V Option Used*	Summary of M&V Plan Requirements, Performance Year M&V Activities

*M&V options A, B, C, and D and methods proposed for each ECM/WCM shall comply with the latest version of the "DOE/FEMP M&V Guidelines: Measurement and Verification for Performance-Based Projects."

1.3 Summary of Estimated and Verified Energy and Cost Savings and Impacts Due to Performance and O&M Issues.

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

1.3.1 Include completed Tables E-1 through E-3.

Table E-1. Estimated Annual Savings Overview

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

ECM / WCM	Total energy savings (MMBtu/year) **	Electric energy savings (kWh/year)	Electric demand savings (kW/year)*	Natural gas savings (MMBtu/year)**	Water savings (kGal/year)	Other energy savings (MMBtu/year)**	Total energy & water cost savings, Year # ($/year)	Other energy-related O&M cost savings, Year # ($/year)	Total cost savings, Year # ($/year)	Total GHG Emission Reductions (kg CO_2e)
Total Savings										
Year [#] guaranteed cost savings:$										

Notes

MMBtu = 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 MMBtu, note energy savings type and provide a conversion factor to MMBtu for link to task order schedules (e.g., 0.003413 MMBtu/kWh).
Guaranteed cost savings for project are defined in TO Schedule 1 (final) of the task order. Estimated savings for each ECM/WCM are included in TO Schedule 4 of the task order.

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

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

ECM / WCM	Total energy savings (MMBtu/year) **	Electric energy savings (kWh/year)	Electric demand savings (kW/year)*	Natural gas savings (MMBtu/year)**	Water savings (kGal/year)	Other energy savings (MMBtu/year)**	Total energy & water cost savings, Year # ($/year)	Other energy-related O&M cost savings, Year # ($/year)	Total cost savings, Year # ($/year)	Total GHG Emission Reductions (kg CO_2e)***
Total savings										

Notes

MMBtu = 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 MMBtu, note energy savings type and provide a conversion factor to MMBtu for link to task order schedules (e.g., 0.003413 MMBtu/kWh).
***Describe factor(s) used in determining GHG emission reductions (e.g., eGRID sub-region, year for electric emission factors).

[Table E-3 is to summarize the variance to guaranteed savings as verified per the M&V plan and RRP Matrix. It also shows an estimated net variance to the guarantee when including impacts to cost savings due to Government actions that are outside the contractor's (ESCO) responsibility. Government impacts to savings may include, but are not limited to, changes to operational hours, heating/cooling set point deviations, physical alterations, and removal of equipment.]

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

I. Per M&V Plan and RRP Matrix	**Energy (MMBtu)**	**Water (kGal)**	**($)**	**Responsibility**
a. Estimated Cost Savings [from Table E-1]				ESCO
b. Verified Cost Savings [from Table E-2]				ESCO
c. Guaranteed Cost Savings [from Table E-2]	N/A	N/A		ESCO
d. Variance to Guarantee (b. - c.)	N/A	N/A		ESCO
II. Estimated Government Impact to Savings	**Energy (MMBtu)**	**Water (kGal)**	**($)**	**Responsibility**
e. Government Impact on ECMs/WCMs (Estimated change to energy/water/cost savings, express losses as negative, increases as positive)*				Government (Ordering Agency)
f. Net Energy, Water, and Cost Savings to Government (b. + e.)				
g. Net Variance (f. - c.)	N/A	N/A		

*If government impact on ECMs/WCMs, include completed table E-4

1.4 Savings Adjustments

1.4.1 Provide summary of any estimated energy, water, and/or cost savings adjustments in Table E-4A.

- Specify whether the adjustment(s) is/are routine or non-routine and provide the reason for any adjustments.

Table E-4A. Detail of ECM/WCM Project Savings Adjustments

ECM / WCM No.	**ECM/WCM Location**	**Impact to Energy Savings (MMBtu)**	**Impact to Water Savings (kGal)**	**Impact to Cost Savings ($)**	**Adjustment Type (Routine, Non-Routine)**	**Reason for Adjustment(s)**

1.5 Performance and O&M Issues

1.5.1 Detail any deficiencies that need to be addressed by the ESCO or the Government in Table E-4.

- Include recommended corrective actions.

1.5.2 Note impact of operating deficiencies or enhancements on generation of savings.

1.5.3 Note impact of maintenance deficiencies on generation of savings.

1.5.4 Detail changes or impacts that have affected the ability of the project to generate savings, including, but not limited to:

- Facility, building or equipment operational changes;
- Occupancy changes;
- Alteration, replacement, or removal of equipment;
- Building additions; and
- Building (partial or whole) demolitions.

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

ECM / WCM No.	ECM/WCM Location	Impact to Energy Savings (MMBtu)	Impact to Water Savings (kGal)	Impact to Cost Savings ($)	Cause of Savings Impact	ESCO Recommended Corrective Action(s)	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, O&M and other 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 - Include completed Table E-5.

1.7.1 Include current TO schedules, as Appendix A

1.7.2 Include list of Government's (ordering agency) review comments and responses to annual M&V reports, along with running list of each previous year's comments and responses, as Appendix B.

1.7.3 Include a "running log of impacts" to document continual changes or impacts that have affected the ability of the project to generate energy and/or water savings for each performance year to date, as Appendix C.

1.8 eProject Builder Output

1.8.1 Include the results of eProject Builder output, as Appendix D.

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

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

Year #	Total energy savings (MMBtu/year)**	Electric energy savings (kWh/year)	Electric demand savings (kW/year)*	Natural gas savings (MMBtu/year)**	Water savings (kGal/year)	Other energy savings (MMBtu/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: MMBtu = 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 MMBtu, note energy savings type and provide a conversion factor to MMBtu for link to task order schedules (e.g., 0.003413 MMBtu/kWh).

2. Details for Each ECM / WCM [Name/#]

Develop section for each ECM/WCM.

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

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 FEMP M&V Guidelines version and option used.

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

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

2.1.5 Provide an overview of savings calculation methods for ECM/WCM.

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

2.2 M&V Activities Conducted This Period

2.2.1 Detail measurements, monitoring, and inspections conducted this reporting period in accordance with M&V plan (include all that apply for each one):

- Measurement equipment used and associated equipment calibration documentation.
- Operation, preventive maintenance, and repair and/or replacement documentation provided or received and reviewed.
- Ensure that inspections and measurements conducted by the ESCO are witnessed by the ordering agency. Include dates/times of data collection or inspections, names of personnel, and documentation of Government witnessing. Include copies of witnessing documentation, as Appendix E.
- Details to confirm adherence to sampling plan, as applicable.
- 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.).
- Describe how performance criteria have been met.
- Note impact of performance deficiencies or enhancements on generation of savings. Detail any performance deficiencies that need to be addressed by the ESCO or the Government.

2.3 Verified Savings Calculations and Methodology

2.3.1 Provide detailed description of analysis methodology 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 Include details of any baseline or savings adjustments made.

- Specify whether the adjustment(s) is/are routine or non-routine and provide the reason for any adjustments.

2.3.5 Detail energy and water rates used to calculate cost savings (if different from section 1.6 of this appendix).

- Provide post-acceptance 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 ECM / WCM for performance year.

- Include completed Table E-6 for current performance year.

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

2.4.1 Describe source of savings, if applicable.

2.4.2 Describe verification activities.

2.4.3 Provide post-acceptance performance period O&M cost savings adjustment factors, if applicable and different from section 1.6 of this appendix.

2.5 O&M Activities

2.5.1 Operating requirements include the following:

- State organization(s) responsible for equipment operations. If appropriate, detail how responsibilities are shared.
- Summarize the key operating procedures, operating records (whether ESCO or Government) and any related verification activities.
- Detail witnessing Government (ordering agency) witnessing activities of ESCO/Contractor's performance of ECM/WCM operations.
- Detail any deficiencies that need to be addressed by the ESCO and/or the Government.
- Note impact of operating deficiencies or enhancements on generation of savings.

2.5.2 Preventive maintenance requirements include the following:

- State the organization(s) responsible for performing maintenance. If appropriate, detail how responsibilities are shared.

- Summarize the key preventive maintenance procedures, preventive maintenance records (whether ESCO or Government) and any related verification activities completed by ESCO or Government.
- Detail witnessing Government (ordering agency) witnessing activities of ESCO/Contractor's performance of ECM/WCM preventive maintenance.
- Detail any deficiencies that need to be addressed by the ESCO and/or the Government.
- Note impact of maintenance deficiencies on generation of savings.

2.5.3 Repair and replacement requirements include the following:

- State the organization(s) responsible for repair and replacement activities. If appropriate, detail how responsibilities are shared.
- Summarize the repair and replacement records (whether ESCO or Government) and activities conducted this period by the ESCO and/or the Government.
- Detail witnessing Government (ordering agency) witnessing activities of ESCO/Contractor's performance of ECM/WCM repair and/or replacement.
- Detail any deficiencies that need to be addressed by the ESCO and/or the Government.
- Note impact of maintenance deficiencies on generation of savings.

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

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

	Total energy use (MMBtu/ year)**	Electric energy use (kWh/ year)	Electric energy cost, Year # ($/year)	Electric demand (kW/year)*	Electric demand cost, Year # ($/year)	Natural gas (MMBtu/ year)**	Natural gas cost, Year # ($/year)	Water use (kGal/year)	Water cost, Year # ($/year)	Other energy use (MMBtu/ year)**	Other energy cost, Year # ($/year)	Other energy-related O&M costs, Year # ($/year)	Total costs, Year # ($/year)	Total GHG Emission Reductions (kg CO_2e)***
Baseline use														
Performance Year # use														
Savings														

Notes

MMBtu = 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 MMBtu, note energy savings type and provide a conversion factor to MMBtu for link to cost schedules (e.g., 0.003413 MMBtu/kWh).
***Describe factor(s) used in determining GHG emission reductions (e.g., eGRID sub-region, year for electric emission factors).

3. Appendices

3.1 Appendix A - Provide a copy of the current TO schedules.

3.2 Appendix B - Provide a list of the Government's (ordering agency) review comments and responses, along with a running list of each previous year's comments and responses.

3.3 Appendix C - Running log of impacts for each performance year.

3.4 Appendix D - Provide an electronic copy of eProject Builder output tables for current performance year.

3.5 Appendix E - Provide copies of Government's (ordering agency) witnessing documents (if applicable).

APPENDIX F. ADDITIONAL RESOURCES

A variety of guidance and resources for all phases of ESPC projects may be found on the FEMP Resources for Implementing Federal Energy Savings Performance Contracts web page. While developed specifically for federal ESPCs; much of the guidance will be of use to any performance-based contracting customer. The current version of guidance and resource documents are available, as well as archived versions at the links below, as applicable.

Documents specifically related to M&V include the following:

- **How to Determine and Verify Operating and Maintenance (O&M) Savings in Energy Savings Performance Contracts**
- **Guidance on Utility Rate Estimations and Weather Normalization in an ESPC**
- **Reviewing Measurement & Verification Plans for Federal ESPC Projects**
- **Reviewing Post-Installation and Annual Reports For Federal ESPC Projects**
- **Including Retro-commissioning in Federal Energy Saving Performance Contracts**
- **Commissioning Guidance for ESPCs**
- **Enhancing Performance Contracts with Monitoring-Based Commissioning**
- **Example M&V Plan for an ESPC Project**