Measurement and Verification (M&V) Guidelines for Energy Saving Performance Contracts in State of Colorado Facilities

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SCHEDULE F:

SAVINGS MEASUREMENT AND CALCULATION FORMULAE; MONITORING AND VERIFICATION PLAN

This schedule contains a description of the energy savings measurement, monitoring and calculation procedures used to verify and compute the savings performance of the installed equipment will be contained in this schedule. The measurement and verification (M&V) Plan should follow the attached M&V Plan and Savings Calculation Methods Outline to help ensure plans are complete and consistent.

In addition, the Agency should require the Contractor to use M&V Guidelines for Energy Saving Performance Contracts in State of Colorado Facilities dated April 2008 along with the International Performance Monitoring and Verification Protocol 2007(IPMVP 2007) as the basis of the savings calculation and verification methodology. These protocols provide four options for M&V and covers all possible energy and water efficiency measures. IPMVP is the accepted international standard for M&V of performance contracts, and the State of Colorado M&V Guidelines provide specific methodologies for the most common measures.

The calculations will include methods to compare the level of energy that would have been consumed without the project (referred to as the "Baseline") with what amount of energy was actually consumed during a specific time period (monthly, quarterly, etc.). All methods of measuring savings including engineered calculations, metering, equipment run times, pre- and post-installation measurements, etc. should be explicitly described for all equipment installed.

A clear methodology for converting energy savings into energy cost savings should be provided. The utility rates to be used for the baseline and actual energy costs should be defined. How the calculations are affected by rising or lowering utility rates should be clearly described.

Clearly predictable annual variations are usually handled through established procedures for each identified factor (e.g., weather, billing days, occupancy, etc.) in the savings formulas. Any routine adjustments that will be made during the performance period must be explicitly defined in this schedule.

Non-routine adjustments may be required for issues such as changes in production shifts, facility closures, adding new wings or loads (such as computer labs) require a conceptual approach versus a method to cover each eventuality. Specify how permanent changes, such as changes in square footage, will be handled. Options include use of agreement clauses that allow predictable or expected changes and/or through a "re-open" clause that allows either party to renegotiate the baseline.

A Facility Changes Checklist or other method may be provided by the Contractor for the Agency to notify the Contractor of any changes in the facility that could have an impact on energy use (occupancy, new equipment, hours of use, etc.). This checklist is generally submitted on a monthly or quarterly basis.

Contents

1. Overview of Measurement and Verification for State ESPCs

This document contains procedures and guidelines for quantifying the savings resulting from energy and water savings projects implemented through ESPCs at State of Colorado facilities.

The "performance" aspect of performance contracting refers to energy performance and is the basis on which savings are determined. Since the measurement and verification (M&V) approach determines how energy savings are calculated and verified over time, it is one of the most important activities associated with implementing performance contracts and is a crucial issue in contract negotiations.

This document has two primary purposes:

- It provides an overview of M&V methods and procedures that should be followed in ESPC projects implemented at State of Colorado facilities,
- It outlines specific procedures that should be used for the most common energy conservation measures (ECMs), including: lighting upgrades, variable speed drives, constant speed motors, water measures, control measures, boiler replacements, chiller replacements, solar thermal systems, transpired solar collectors, and photovoltaic systems.

1.1 Why Measure and Verify?

Energy performance contracts are based on "guaranteed savings." Any authentic guarantee of energy and cost savings includes adequate measurement and verification (M&V) activities. For Colorado state agencies, a savings guarantee is required for at least the first three years of a performance contract[1]. For Colorado local governments, the savings guarantee is required for at least the first two years[2]. The savings guarantee is defined by the M&V activities, whose function is to reduce agency risk by substantiating estimated savings. The challenge of M&V is to balance M&V costs and savings certainty with the value of the conservation measure.

There are many reasons to use M&V strategies that go far beyond satisfying the law. Properly applied, M&V can:

- Accurately assess energy savings for a project;
- Allocate risks to the appropriate parties;
- Reduce uncertainties to reasonable levels;
- Ensure that the agency achieves utility budget savings;
- Monitor equipment performance;
- Find additional savings;
- Improve operations & maintenance;

[1] Per Colorado statue CRS 24-30-2001

[2] Per Colorado statue CRS 29-12.5-2000

- Verify savings guarantee is met;
- Allow for future adjustments, as needed.

1.2 General Approach to Determining Energy Savings

Facility energy (or other) savings cannot be measured, since they represent the absence of energy use. Instead, savings are determined by comparing the energy use before and after the installation of conservation measure(s), making appropriate adjustments for changes in conditions.

The "before" case is called the baseline. The "after" case is referred to as the post-installation or performance period. Proper determination of savings includes adjusting for changes that affect energy use, but that are not caused by the conservation measure(s). Such adjustments may account for changes in weather, occupancy, or other factors between the baseline and performance periods. Equation 1 shows the general equation used to calculate savings.

$$Savings = (Baseline \quad Energy - Post \quad Installation \quad Energy) \pm Adjustments \qquad \text{(Eq.1)}$$

Baseline and post-installation energy use can be determined by using the methods associated with several different M&V approaches. These approaches, originating in the International Performance Measurement and Verification Protocol (IPMVP), are termed Options A, B, C, and D. A range of options enables one to apply suitable techniques for a variety of applications. How one chooses and tailors a specific option is determined by the level of M&V rigor required to obtained the desired accuracy level in the savings determination and is dependent on the complexity of the conservation measure, the potential for changes in performance, the measure's savings value, and the project's allocation of risk.

There are two fundamental factors that drive energy savings: performance and usage. Performance describes the amount of energy used to accomplish a specific task, and may also be referenced as efficiency or rate of energy use. Usage describes the operating hours, or total time, that a piece of equipment runs.

The energy consumption is generally determined by multiplying performance (or efficiency) by usage (or operating hours). In all cases, these factors need to be known for both the pre- and post-retrofit conditions to determine energy consumption and savings, as shown in Figure 1.

Savings are determined by comparing the energy use of the pre-retrofit case, called the *baseline*, with the post-retrofit energy use. This means that the performance and usage factors must be known for both the baseline and post-retrofit cases in order to determine energy savings, as shown in Figure 1.

In addition, as shown in Equation 1, both routine and non-routine adjustments may be used to account for any changes that may occur during the performance period. The purpose of adjustments is to express both baseline and post-installation energy under the same set of conditions.

Routine adjustments are used to account for expected variations in independent variables and energy use. Regression analysis is often used to correlate energy use to independent variables such as weather. Routine adjustments are used to normalize energy use as a function of one or more independent parameters such as temperature, humidity, or meals served[3]. When routine adjustments are anticipated, a project-specific M&V plan should identify critical independent variables, explain how these variables will be measured or documented, and discuss how they will be used in the empirical models. The methods and data that will be used to develop any post-installation models during the performance period must also be specified in the M&V Plan.

Non-routine adjustments are used to compensate for unexpected changes in energy driving factors, such as facility size, operating hours, and facility use. These factors must be monitored for change during the post-installation period to ensure that they are not affecting the performance of the energy conservation measure.

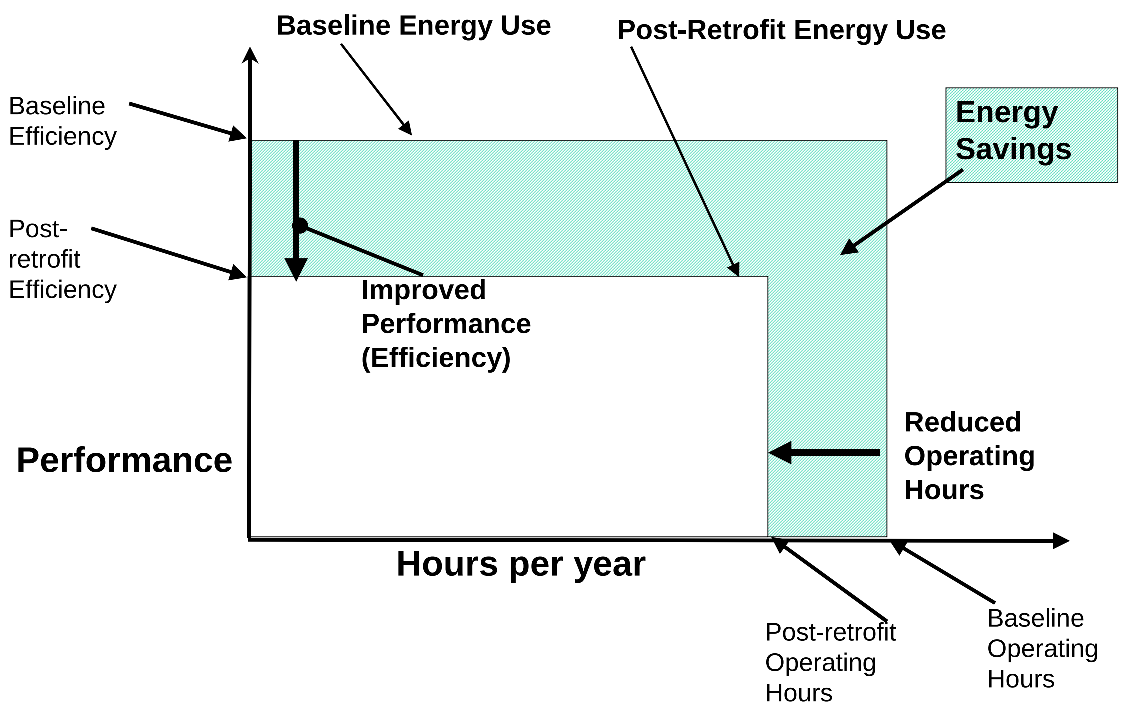

Figure 1: Energy Savings Depend on Performance and Usage

In Figure 1, the area of the large box represents the total energy used in the baseline case. Reduction in either the rate of energy use (increase in performance) or in usage (decrease in operating hours) leads to reduced total energy use, as shown by the smaller box. The difference between the two boxes—the shaded area—represents the energy savings.

Lighting provides a simple example: performance would be the watts required to provide a specific amount of light; usage would be the operating hours per year. Lighting energy used is equal to watts * operating hours, as shown below.

$$kWh = (\text{watts*operating hours})/1000$$

[3] See IPMVP or FEMP M&V Guidelines for more information on normalizing savings.

A chiller is a more complex system: performance is defined as kW/ton, which varies with load; usage is defined by cooling load profile and ton-hours. Chiller energy must be analyzed on an hourly basis because equipment efficiency varies with loading, and is equal to Sum [kW/ton * ton/hours], as shown below.

$$\text{kWh} = \sum (\text{kW/ton}) * (\text{tons}) * (\text{operating hours})$$

Electric demand savings are more complex to calculate than energy savings. Charges are typically based on a short-term peak demand charge which depends on rate structures and variability in loads. Determining peak demand savings often requires measurements of increased frequency, often every 15 minutes.

1.3 Using M&V to Allocate Risk

One of the primary purposes of M&V is to reduce risk to an acceptable level, which is a subjective judgment based on the agency's priorities and preferences. In performance contracts, risks are allocated between the energy service companies (ESCO) and the state agency. Allocation of risk is accomplished through carefully crafted M&V strategies.

"Risk" in the M&V context refers to the uncertainty that expected savings will be realized. Assumption of risk implies acceptance of the potential monetary consequences. Both ESCOs and agencies are reluctant to assume responsibility for factors they cannot control, and stipulating certain parameters in the M&V plan can assign responsibility to each party for the parameters they are best able to control. For example, usage factors under the agency's control such as equipment operating hours and cooling load profiles are typically stipulated. Using stipulations means that the ESCO and agency agree to use a set value for a parameter throughout the term of the contract, regardless of the actual behavior of that parameter.

If no values are stipulated and savings are verified based entirely on measurements, then more of the risk resides with the ESCO, which must show that the guaranteed savings are realized, or prove how contributing factors affected the result. Alternatively, the agency assumes the risk for the parameters that are stipulated. In the event that the stipulated values overstate the savings, the agency will not be able to claim the actual shortfall from the ESCOs guarantee. However, if the actual savings are greater than expected due to improperly stipulated values, then the agency benefits from the surplus savings.

Risk related to usage stems from uncertainty in operational factors. For example, savings fluctuate depending on weather, how many hours equipment is used, user intervention, or maintenance practices. Since ESCOs often have no control over such factors, they are usually reluctant to assume usage risk. The agency generally assumes responsibility for usage risk by either allowing baseline adjustments based on measurements, or by agreeing to stipulate equipment operating hours or other usage-related factors.

Performance risk is the uncertainty associated with characterizing a specified level of equipment performance. The ESCO is ultimately responsible for selection, application, design, installation, and performance of the equipment and typically assumes responsibility for achieving savings related to equipment performance. To validate performance, the ESCO must demonstrate that the equipment is operating as intended and has the potential to deliver the guaranteed savings.

Using stipulated values in savings estimates can be a practical, cost-effective way to minimize M&V costs and allocate risks for some projects. Stipulations, if used appropriately, do not jeopardize the savings guarantee, the agency's ability to pay for the project, or the value of the project to the government. However, stipulations shift risk to the agency, and the agency should thoroughly understand the potential consequences before accepting them. Risk is minimized through carefully crafted M&V requirements often including rigorous measurements to properly determine any stipulated values.

2. Primary Steps to Verify Savings

In general, determining actual savings achieved can be difficult and costly. In many performance contracts, it is more important to verify the potential of the ECM to generate the predicted savings. Verifying the potential to generate savings can also be stated as confirming that:

- The baseline conditions were accurately defined,
- The proper equipment/systems were installed and are performing to specification, and
- The equipment/systems continue to have the potential to generate the predicted savings.

Regardless of the M&V option used, similar steps are taken to determine and verify a project's performance. These steps are outlined in Table 1 below, and the steps are discussed in detail below.

Table 1: Steps to Verify Project Performance

Timing		Activity
Before Project Implementation	Step 1	Allocate project responsibilities
	Step 2	Develop a project-specific M&V plan
	Step 3	Define the baseline
During Project Implementation	Step 4	Install and commission equipment and systems
	Step 5	Conduct post-installation verification activities
After Project Implementation	Step 6	Perform regular-interval verification activities during the performance period

2.1 Step 1: Allocate Project Responsibilities

The basis of any project-specific M&V plan is determined by the allocation of key project responsibilities between the ESCO and the agency involved. The distribution of responsibilities will depend on the agency's resources and preferences, and the ESCO's ability to control certain factors. A useful tool in allocating key risk elements is the Risk-Responsibility Matrix located in the appendices.

2.2 Step 2: Develop Project Specific M&V Plan

The M&V plan is the single most important item in defining any energy savings "guarantee." The plan defines how savings will be calculated and specifies any ongoing activities that will occur during the contract term.

Although the M&V plan is usually developed during contract negotiations, it is important that the agency and the ESCO agree upon general M&V approaches to be used prior to starting the detailed Technical Energy Audit (TEA). The M&V method(s) chosen can affect how the baseline is defined, determining what level of measurements are required during the audit.

The project-specific M&V plan includes project-wide items as well as details for each ECM. It is strongly recommended that the format of M&V Plan included in the ESCO's Final Proposal follows the attached Measurement and Verification Plan Outline,[4] which was originally developed by the DOE.

Project-wide items included in M&V Plan:

- Overview of proposed energy and cost savings
- Snapshot of total facility energy use (optional)
- Schedule for all M&V activities
- Agency witnessing requirements of M&V activities
- Utility rates and the way they will be used to calculate cost savings
- Operations and maintenance (O&M) reporting responsibilities

ECM-level items included in M&V Plan:

- Details of baseline conditions and data collected
- Documentation of all assumptions and sources of data
- Details of engineering analysis performed
- How energy and cost savings will be calculated
- Details of O&M cost savings claimed
- Detailed baseline energy and water rates.
- What will be verified
- Who will conduct the M&V activities
- Discussion on risk allocation and savings uncertainty
- Performance period adjustment factors for energy, water, and O&M rates, if used[5].

[4] M&V Plan Outline from GEO is attached

[5] Use NIST data to determine maximum allowable utility escalation factor. See DOE's Energy Escalation Rate Calculator (EERC 1.0-04) at http://www.eere.energy.gov/femp/information/download_blcc.cfm.

- How & why any adjustments will be made
- Preventive maintenance responsibilities
- Content and format of all M&V reports (Post-Installation M&V Report and Annual M&V Reports)

2.3 Step 3: Define the Baseline

Typically the ESCO defines the baseline as part of a TEA. Baseline physical conditions (such as equipment inventory and conditions, occupancy, nameplate data, energy consumption rate, control strategies, and so on) are typically determined during the TEA through surveys, inspections, spot measurements, and short-term metering activities. Baseline conditions are established for the purpose of calculating savings by comparing the baseline energy use to the post-installation energy use. Baseline data are also used to account for any changes that may occur during the performance period, which may require routine or non-routine adjustments.

Baseline data should include sufficient data to account for expected variations in independent variables and energy use. Any empirical models that will be used for these routine adjustments of the baseline must be defined.

Baseline data must also document the existing conditions at the time of project implementation in order to provide a basis for non-routine adjustments. Examples of non-routine adjustments include: change in the amount of space being air conditioned, changes in auxiliary systems (towers, pumps, etc.), and changes in occupancy or schedule. For example, if a chiller retrofit was completed in a building with 100,000 square feet of conditioned space and during the contract term the conditioned space is reduced to 75,000 square feet, post-installation energy use would be lower making savings higher. If there are no records of the amount of originally conditioned space, the baseline could not be adjusted.

In almost all cases after an ECM has been implemented, one cannot go back and re-evaluate the baseline. It no longer exists! Therefore, it is very important to properly define and document the baseline conditions. Deciding what needs to be monitored (and for how long) depends on factors such as the complexity of the measure and the stability of the baseline, including the variability of equipment loads and operating hours, and the number of variables that affect the load. This baseline information is included in the ESCO's Final Proposal. It is the agency's responsibility to ensure the baseline has been properly defined.

2.4 Step 4: Install and Commission Equipment and Systems

Commissioning of installed equipment and systems is considered industry best-practice, and is required in State ESPC projects as detailed in *Schedule H: System Start-Up and Commissioning* of the State of Colorado ESPC master contract. Commissioning ensures that systems are designed, installed, functionally tested in all modes of operation, and are capable of being operated and maintained in conformity with the design intent (temperature setpoints, lighting levels, tons of cooling, etc.) Commissioning activities include inspections and functional testing, which are specified in a Commissioning Plan, and their results are documented in a Commissioning Report.

Commissioning guidelines, similar to these M&V guidelines, are included in *Schedule H: System Start-Up and Commissioning* of the State of Colorado ESPC master contract. In addition, *Schedule H* of each contract will specify the project specific details of the commissioning approach that will be followed. Some of the key issues that are covered in *Schedule H* include the qualifications and affiliation of the Commissioning Agent (CxA); roles and responsibilities of CxA, ESCO, and agency; and the process that will be followed, including key deliverables.

The commissioning process ensures equipment was properly installed and is operating to specification, which often requires taking performance measurements. M&V activities, however, quantify how well the systems are working from an energy standpoint. Because of the overlap in commissioning and measurement and verification (M&V) activities, some people may confuse the two.

2.5 Step 5: Post-Installation Verification

After commissioning activities are completed, the M&V activities specified in the contract are implemented. Verification methods may include surveys, inspections, spot measurements, and short-term or long-term metering.

Post-installation verification activities are conducted immediately after project completion, usually before final project acceptance. Activities may be conducted by both the ESCO and the agency to ensure that proper equipment/systems were installed, are operating correctly, and have the potential to generate the predicted savings.

The verification of project performance is accomplished by executing both the commissioning and M&V activities prescribed in the contract. As mentioned above, commissioning focuses on ensuring the equipment and systems were installed and are operating properly, whereas M&V focuses on quantifying the energy impacts from installing the new equipment. Both commissioning and M&V must be completed prior to project acceptance, and the results from each effort will be presented in separate reports delivered by the ESCO.

<u>Post-Installation M&V Report</u>

The results of the measurement and verification activities conducted immediately following project installation are documented in a Post-Installation Report. Although this report is not mandated by the State of Colorado's master ESPC contract, its use is strongly recommended. The Post-Installation Report documents the results of M&V activities conducted after project implementation, as well as any changes in the contracted project scope and the expected energy savings based on the actual installed conditions, confirming or updating estimated values regarding the performance of the new equipment. A Post-Installation Report provides an important piece of project documentation as it accounts for any project changes that may otherwise be unclear in retrospect.

For ECMs using any stipulated values to calculate energy savings, the post-installation verification can be the most important M&V step since any measurements to substantiate the savings guarantee are often made only once. Thereafter, inspections may be conducted to verify that the 'potential to perform' exists.

It is strongly recommended that the format of the Post-Installation Report follows the Post-Installation Report Outline[6] developed by GEO. The Post-Installation Report includes:

- Project description
- Installation verification – list of installed equipment
- Details of any changes between Contract and as-built conditions, including energy impacts
- Documentation of all post-install verification activities and performance measurements conducted
- Performance verification – how performance criteria were met
- Validation of construction-period savings (if any)
- Status of rebates or incentives (if any)
- Expected savings for the first year

If a Post-Installation Report is not provided for a project, it is important that the first year M&V Report covers these topics.

2.6 Step 6: Periodic Performance Period Verification

For at least the first two or three years[7] after installation, the ESCO is required to submit an Annual M&V Report documenting the savings actually achieved. Inspections should confirm that the installed equipment/systems have been properly maintained, continue to operate correctly, and continue to have the potential to generate the predicted savings. In many cases, equipment performance measurements should be used to substantiate savings. Sometimes, more frequent verification activities can be appropriate. This ensures that the M&V monitoring and reporting systems are working properly, it allows fine-tuning of measures throughout the year based on operational feedback, and it avoids surprises at the end of the year.

At the agency's option, the savings guarantee can be extended beyond the legislatively required 2 to 3 years. For more complex projects, ongoing M&V activities can help ensure the persistence of savings.

At the end of each performance year (as specified in the Schedule F of the contract), the contractor submits an Annual M&V Report to demonstrate that the savings have occurred. Depending on the M&V method used, savings from individual ECMs will usually be quantified. It is important to recognize that the Contractor must demonstrate that the overall savings guarantee has to be met on a cumulative basis for all ECMs, and the performance of each ECM is not specifically guaranteed.

It is strongly recommended that the format of Annual Report follows the Annual Report Outline[8] developed by GEO. The Annual M&V Reports should include:

[6] Post-Installation Report Outline from GEO is attached

[7] Colorado legislative requirement for state agencies is 3 years; requirement for local agencies is 2 years

[8] GEO Annual M&V Report Outline is attached

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

3. M&V Protocols and Methods

Measuring and verifying savings from performance contracting projects requires special project planning and engineering activities. M&V continues to evolve with the performance contracting industry, although common practices exist. These practices are documented in several guidelines including the *International Performance Measurement & Verification Protocol*[9] (IPMVP, 2007), FEMP *M&V Guidelines: Measurement and Verification for Federal Energy Projects* Version 2.2[10] (2000), and ASHRAE *Guideline 14: Measurement of Energy and Demand Savings*[11] (2002).

Many industry professionals consider the IPMVP the standard protocol for conducting M&V on energy saving projects. The IPMVP is available through http://www.evo-world.org/.

IPMVP groups M&V methodologies into four categories: Options A, B, C, and D. The options are generic M&V approaches for energy and water saving projects. Having four options provides a range of approaches to determine energy savings depending on the characteristics of the ECMs being implemented, and balancing the accuracy in energy savings estimates with the cost of conducting M&V activities. The description of these options provided here-in are a cursory overview, and additional details are provided in the IMPVP 2007.

M&V approaches are divided into two general types: retrofit isolation and whole facility. Retrofit isolation methods look only at the affected equipment or system independent of the rest of the facility; whole facility methods consider only the total energy use while ignoring specific equipment performance. Options A and B are retrofit isolation methods; Option C is a whole facility method. Option D can be used as either, but is usually applied as a whole facility method. The differences in these approaches are shown in Figure 2.

[9] *International Performance Measurement and Verification Protocol: Concepts and Options for Determining Energy and Water Savings Volume I*, EVO-10000 -1.2007, Efficiency Valuation Organization.

[10] Version 2.2 is currently available and Version 3.0 of the FEMP M&V Guidelines is scheduled for release in April 2008 and will be available through http://www.eere.energy.gov/femp/financing/superespcs_mvresources.cfm.

[11] *ASHRAE Guideline 14-2002: Measurement of Energy and Demand Savings*, American Society of Heating, Refrigerating and Air-Conditioning Engineers.

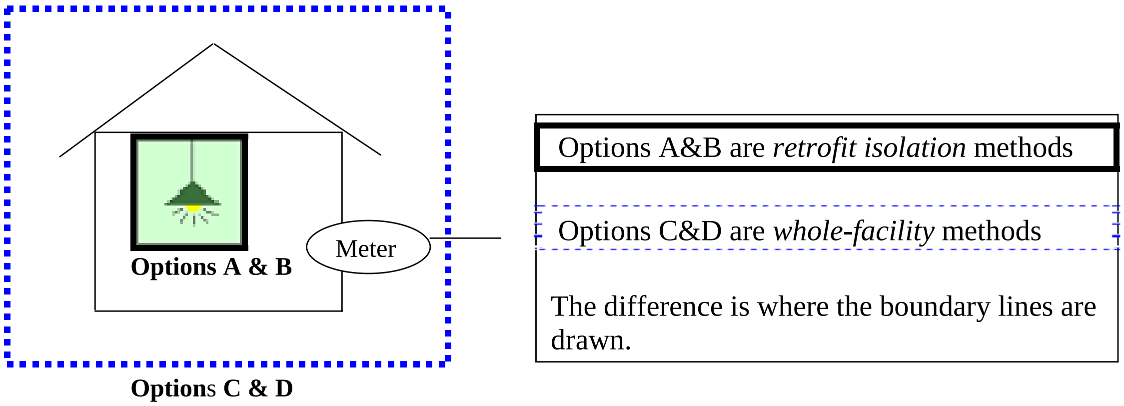

Figure 2: Retrofit Isolation vs. Whole-Facility M&V Methods

The four generic M&V options are described in more detail below. Each option has advantages and disadvantages based on site-specific factors and the needs and expectations of the agency. While each option defines a savings determination approach, all savings are estimates since savings cannot be directly measured. Generally, the accuracy of savings estimates improves as more measurements are used in defining the baseline and monitoring the post-installation conditions. The improved accuracy in savings estimates must be weighed against higher M&V costs on a case-by-case basis. For example, smaller projects that have high M&V costs associated with them may have secondary benefits, such as non-energy or maintaining a customer relationship. The decision to perform an appropriate amount of M&V data collection for small projects should be joint decision between the owner and the ESCO.

3.1 Option A –Retrofit Isolation with Key Parameter Measurement

Option A is a retrofit isolation or system level approach designed for projects in which the potential to generate savings must be verified, but the actual savings can be determined from short-term data collection, engineering calculations, and stipulated factors. The approach is intended for retrofits where key performance factors (e.g., end-use capacity, demand, power) or operational factors (lighting operational hours, cooling ton-hours) can be spot- or short-term-measured during the baseline and post-installation periods. Any factor not measured is estimated based on assumptions, analysis of historical data, or manufacturer's data. Post-installation energy use, equipment performance, and usage are NOT measured throughout the term of the contract.

The intent of Option A is to verify performance through pre- and post-retrofit measurements. Usage factors can be measured or stipulated based upon engineering estimates, operating schedules, operator logs, typical weather data, or other documented information source. Post-retrofit measurements are made only once. Thereafter, inspections only verify that the 'potential to perform' exists. So long as the 'potential to perform' is verified, the savings are as originally claimed and do not vary over the contract term.

Option A methods are appropriate for less complex measures whose performance and operational characteristics are well understood and are unlikely to change. An Option A approach can also be suitable when the value of the measure's cost savings are low. Examples of projects where Option A may be appropriate include one-for-one lighting replacement measures, high efficiency motors with constant loads, or measures with a small percentage of overall cost savings.

3.2 Option B – Retrofit Isolation with All Parameter Measurement

Option B is a retrofit isolation or system level approach, whose procedure includes the same items as Option A, but requires more end-use metering. Option B uses periodic or continuous metering of all energy quantities or all parameters needed to calculate energy use, during the post-installation period to provide long-term verification of the savings. This method is intended for retrofits with performance factors and operational factors that can be measured at the component or system level and where long-term performance needs to be verified. Option B is similar to Option A but uses periodic or continuous metering to determine energy use. Short-term periodic measurements can be used when variations in the measured factor are small. Continuous monitoring information can be used to improve or optimize the operation of the equipment over time, thereby improving the performance of the retrofit.

The intent of Option B is to verify performance periodically or continuously with long-term measurements. Usage factors may be stipulated as in Option A or measured continuously.

Option B methods are appropriate for complex systems whose load or operating conditions are not well known or are highly dependent on external factors. Examples of projects where Option B may be appropriate include variable speed drive (VSD) installations, modifications to control systems, chiller system upgrades, or ECMs that contribute a high percentage of a project’s overall cost savings.

3.3 Option C – Whole Facility Energy Use

Option C is a whole-building verification method that uses utility or sub-meter data to verify the performance of retrofit projects in which baseline and post-installation data are available. Savings are based on actual energy consumption as measured by the utility meter(s) and often adjusted based on independent variables using regression modeling.

Option C verification methods determine savings by studying overall energy use in a facility. The evaluation of whole-building or facility-level metered data is completed using techniques ranging from simple billing comparison to multivariate regression analysis. Regression analysis can be used to account for weather and other factors to adjust the baseline or post-installation energy use and determine savings.

Option C is an appropriate and cost-effective method ONLY if facility operation is stable and savings are expected to exceed 20% of total energy consumption. However, Option C cannot verify the performance of individual measures but can verify the total performance of all measures including interactions.

Option C methods are appropriate for projects whose measures have a high degree of interaction that would be difficult to predict, when overall energy savings are very large, or when dedicated utility meters are available for retrofitted equipment or systems.

3.4 Option D – Calibrated Simulation

Option D is primarily a whole-building method but can be used at the component level. Savings are based on the results of a calibrated computer simulation model. Estimated savings may vary over the contract term if real weather data is used.

Option D uses a calibrated computer simulation model of component or whole-building energy consumption to determine energy savings. Simulation models must be calibrated to actual baseline and post-installation site conditions, and may involve metering performance and operating factors before and after the retrofit. Specialized software packages, such as eQUEST or Energy Plus[12], are used in Option D. It should be noted that the development of accurate building models requires substantial time and expertise. Statistical validation techniques of comparing actual with predicted energy use are detailed in the FEMP M&V Guidelines[13] and should be used to ensure models are sufficiently accurate. 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.

Option D methods are appropriate for complex projects where complex system interactions need to be tracked. Due to the expense of properly conducting Option D, suitable projects should have substantial cost savings or major building renovations such as window replacements and building insulation.

4. Recommended Measure Specific M&V Methods

Recommended M&V approaches are provided in this section for some of the most common measures, including:

- lighting upgrades,
- variable speed drives,
- constant speed motors,
- water measures,
- controls measures,
- boiler replacements,
- chiller replacements,
- solar thermal systems,
- transpired solar collectors, and

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

[13] FEMP M&V Guidelines is available through http://www.eere.energy.gov/femp/financing/superespcs_mvresources.cfm.

- photovoltaic systems.

These approaches should be used on projects in State of Colorado facilities wherever feasible.

4.1 Lighting Upgrades

Option A

- Measure operating hours for duration of 2 – 3 weeks during audit phase, during non-holiday timeframe. Use sampling plan with 80 / 20 confidence / precision (results in 11 samples per group assuming a Cv of 0.5[14]).
- If hours of operation are well documented and stable, then conservative stipulated hours are acceptable if backed up with some monitoring during the audit.
- Fixture power consumption based on standard tables (utility or EPRI lighting tables) only if inventory of equipment is very accurate (including lamp & ballast types); measure power consumption of unknown or unusual fixture types.
- Use diversity factors to determine demand reduction (% lights on during utility peak)
- Heating penalty, cooling bonus are allowable where appropriate. Provide detailed calculation methodologies[15].

4.2 Variable Speed Drives

Option B

- Baseline operating hours should be measured. Baseline power consumption should be measured; spot power measurements are acceptable for constant loads.
- Post-retrofit operating hours and power (or speed if correlated to power with one-time measurements) should be continuously measured by Energy Management Control System (EMCS), since demand savings are not guaranteed with VSDs (100% speed = 100% load). Adjust the baseline for actual use conditions if needed.

[14] See FEMP M&V Guidelines for detailed information on statistical sampling, available through http://www.eere.energy.gov/femp/financing/superespcs_mvresources.cfm.

[15] See Rundquist, et. al., *Calculating Lighting and HVAC Interactions,* ASHRAE Journal, November 1993, or Sezgen, Osman et. al., *Interactions Between Lighting and Space Conditioning Energy Use in Commercial Buildings,* LBNL-39795, April 1998.

4.3 Constant Speed Motors

Option A

- Baseline operating hours should be measured. If hours of operation are predictable (i.e. 10 hrs/day), stipulate post-retrofit operating hours. If hours of operation are variable or change, measure post-retrofit motor runtime.
- Measure baseline and post-retrofit motor power consumption (depends on load factor, which varies); spot measurements are acceptable for constant loads.
- Differences in either the measured load factor or rotation speed (slip) between the existing motor and a new high-efficiency motor can impact savings. For belt-driven motors, re-sheaving the motor can be an effective way to equalize system performance for changes in motor slip.

4.4 Water Measures

If metering exists and expected savings exceed 20% of metered usage, then use Option C; otherwise use Option A.

Option C

- Establish statistically significant relationship between use and dependent factors (weather, occupancy and/or other use factors) using regression analysis during audit (coefficient of determination R^2 >0.8[16]). Adjust baseline using post-retrofit conditions or normalize post-retrofit data to typical year data.

Option A

- Use if Option C is not applicable.
- Assume consumption (i.e. flushes/day) and ensure water consumption model accounts for no more than 75% of the water bill (ensures conservative load assumptions)
- If irrigation exists then use winter only data to extrapolate to all months.
- Measure pre and post-retrofit fixture flow on a sampling basis (80% / 20%)

4.5 Controls Measures

Option B

- Baseline conditions should be verified through short-term measurements (i.e. document operating hours; demonstrate no economizer or outdoor reset).
- Energy Management Control System (EMCS) should be used to collect all relevant post-retrofit load data (i.e. operating hours, actual cooling delivered by economizer, the hours of temperature reset). Use data in engineering calculations to determine savings.
- Monthly monitoring of data collection recommended.

[16] Additional statistical evaluation techniques that can used to evaluate the validity of a regression model are included in FEMP M&V Guidelines and ASHRAE Guideline 14.

4.6 Boiler Replacement

If metering exists and expected savings exceed 20% of metered usage, then use Option C; otherwise use Option A or B.

Option C

- Establish a statistically significant relationship between energy use and weather and/or other dependent factors (occupancy and/or other use factors) using regression analysis during audit (coefficient of determination R^2 >0.8[17]).
- Analyze post-retrofit use from utility bills or sub-metered data. Adjust baseline using actual weather or normalize post-retrofit data to typical year weather data.

Option A / B

- Operating hours and load should be measured and verified with analysis of utility or ECMS data.
- Baseline combustion efficiency should be measured using a flue gas analyzer. Post-retrofit combustion efficiency should be measured every year.
- Establish relationship between use and weather and/or other dependent factors using regression analysis during audit. Adjust baseline using actual weather or develop regression relationship from post-retrofit data to normalize energy use to typical year weather data.

4.7 Chiller Replacement

Option B is recommended, but Option A may be used if necessary.

Option B

- The range of baseline efficiencies should be determined through measurements (kW/ton). Measurements should cover the expected range of operating conditions including loads and water temperatures.
- If baseline efficiency is estimated, the original (un-degraded) equipment efficiency from the manufacturer's cut sheets or specification should be used.
- Use measured data to develop regression for weather vs. cooling load.
- Post-retrofit: continuously measure load and energy use.
- Apply baseline efficiency to measured load data to determine savings. Adjust baseline using actual weather or normalize post-retrofit data to typical year weather data/loads.

Option A

- Same as Option B, but savings are calculated based on a shorter end-use metering time.
- Make necessary assumptions and extrapolations for unmetered data based on original manufacturing equipment ratings and/or weather data.

[17] Additional statistical evaluation techniques that can used to evaluate the validity of a regression model are included in FEMP M&V Guidelines and ASHRAE Guideline 14.

4.8 Solar Technologies

The performance of solar energy technologies can be estimated using typical year insolation[18] values. Simulation software such as F-CHART[19], RETScreen[20], PV FCHART[21], or PV Watts[22] can be used to model the performance of the systems, or estimates may be based on spreadsheet models using typical meteorological year (TMY3[23]) weather data suitable to the project site. If historical weather data specific to the site is available, that should be used in place of TMY3 weather data. Table 2 summarizes the noted software tools and how they can be applied to the solar technologies described below.

Table 2. Solar Technologies and Applicable Software & Analysis Tools

	Solar Thermal Systems	Transpired Solar Collectors	Photovoltaic Sytems
F-CHART	√	√	√
RETScreen	√	√	√
PV FCHART			√
PV Watts			√
Custom Spreadsheet Analysis Tool	√	√	√

4.8.1 Solar Thermal Systems

Option B is recommended; however, if the the expected consulting costs for monitoring will exceed 20% of the predicted annual savings (i.e., smaller systems), use Option A. For both options, appropriate monitoring (e.g., reviewing monthly utility bills) should be considered since these systems are sometimes bypassed as they require more maintenance over time.

Option B

- Install and use thermal energy metering for long-term monitoring of the energy provided by the system. Thermal metering will consist of a flow meter, temperature sensors (on

[18] Insolation is a measure of electromagnetic energy (solar radiation) incident on the surface of the earth measured in btu/square foot/day.

[19] FCHART is a software tool designed for analyzing passive and active solar thermal systems, and is available for purchase from http://www.fchart.com/

[20] RETSceen provides simplified analysis of many renewable technologies and is available through Natural Resources Canada at http://www.retscreen.net/ang/g_solara.php.

[21] PV FCHART is a software tool designed for analyzing photovoltaic systems. It utilizes typical meteorological year weather data, and is available for purchase at http://www.fchart.com/pvfchart/pvfchart.shtml

[22] PV Watts is a software tool designed for analyzing photovoltaic systems. It utilizes typical meteorological year weather data, and is available at http://www.pvwatts.org/

[23] TMY3 data can be found at http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/

the supply and return), and the data collection device (e.g. energy management control system). For constant flow systems, the flow rate may be determined from one time measurements. Depending on the value of the project, redundant metering equipment may be advisable.

- The amount of energy delivered is determined by multiplying the mass flow rate by the specific heat of the water and the temperature difference between the return and supply.
- The energy provided by a solar thermal system should be measured continuously, and data should be verified at least quarterly. Sensors should be calibrated at least once per year.

Option A

- Initial verification: Confirm all equipment (e.g. collectors, storage tanks, pumps, heat transfer fluid, controls, etc.) ratings match the design specifications, verify that workmanship is of acceptable quality, and confirm performance is as expected. Performance parameters that should be measured include supply flow rates, and temperatures across the collector(s) and heat exchangers. Verify proper operation of the system by monitoring the status of pumps and other controlled items (e.g. valves), as well as the supply and storage tank temperatures for one day up to one week. The key parameters that must be verified are flow rate (gallons per minute), and supply temperatures.
- Periodic verification: Verify proper operation of the system by monitoring the starting and stopping of pumps and any other controlled items (e.g. valves) as well as the supply and storage tank temperatures for at least one day and up to one week. Confirm collectors are clean and no shading has occurred.
- If possible, include continuous monitoring of the water supply temperature to provide a simple indicator of general system performance.

4.8.2 Transpired Solar Collectors

If metering exists and expected savings exceed 20% of metered usage, then use Option C; otherwise use Option A.

Option C

- Establish a statistically significant relationship between energy use and weather and/or other dependent factors (occupancy and/or other use factors) using regression analysis during audit (coefficient of determination $R^2 > 0.8$[24]).
- Analyze post-retrofit use from utility bills or sub-metered data. Adjust baseline using actual weather or normalize post-retrofit data to typical year weather data.

Option A

- Initial verification: Confirm all equipment (e.g. collectors, dampers, fans, temperature sensors, controls, etc.) ratings match the design specifications, verify that workmanship is of acceptable quality, and confirm system performance is as expected (as described below).

[24] Additional statistical evaluation techniques that can used to evaluate the validity of a regression model are included in FEMP M&V Guidelines and ASHRAE Guideline 14.

- Periodic verification: Inspect system for fouling, discoloration, shading, and leaks. Confirm system performance is as expected (as described below).
- Confirm system performance by measuring parameters including supply air flow rates, outside air temperature, supply air temperature from the collector, as well as the operational temperatures of the air-handling unit (return, mixed, and supply air temperatures) or other end use application. Verify proper operation of the system by monitoring the status of fans, supply and bypass dampers, and operational temperatures for one day up to one week. Ensure system does not operate under cooling or economizer conditions.
- Confirm quality and calibration of temperature sensors used.

4.8.3 Photovoltaic Systems

Photovoltaic systems should be verified using Option B, but Option A can be used if necessary.

<u>Option B</u>

- Install permanent data loggers at the AC output of the system and record the power generation. Interval of measurements should correspond to utility intervals if peak demand savings are claimed. The energy provided by a PV system should be measured continuously, and data collected should be verified at least quarterly.

<u>Option A</u>

- Initial verification: Confirm all equipment ratings match the design specifications, verify that workmanship is of acceptable quality, and confirm system performance is as expected (as described below).
- Periodic verification: Inspect system for panel obstruction, shading, and debris. Confirm system performance is as expected (as described below).
- Confirm system performance by measuring output based on solar data during the collection period. Verify proper operation of the system by monitoring the system for one day up to one week.

5. Appendix

M&V Plan and Savings Calculations Methods Outline

Risk-Responsibility Matrix

Post-Installation M&V Report Outline

Annual M&V Report Outline

Appendix to

Measurement and Verification (M&V) Guidelines for Energy Saving Performance Contracts in State of Colorado Facilities

M&V Plan and Savings Calculation Methods Outline

Adopted from DOE's Federal Energy Management Program

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

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

1.1 Proposed Annual Savings Overview

1.1.1 Site Use and Savings Overview (Optional)

- Fill in Table 1A or provide equivalent information.

Table 1. Proposed Annual Savings Overview

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

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

Notes
*Annual electric demand savings (kW/yr) is the sum of the monthly demand savings.
** Units for fuels and water are as denoted in the bills
MMMBtu=1,000,000 Btu.
If energy is reported in units other than MMMBtu, provide a conversion factor to MMMBtu for link to delivery order schedules (e.g., 0.003413 MMMBtu/kWh).

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

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

Notes
MMMBtu=1,000,000 Btu
*Annual electric demand savings (kW/yr) is the sum of the monthly demand savings.
**Define usage period.
*** Units for fuels and water are as denoted in the bills
If energy is reported in units other than MMMBtu, provide a conversion factor to MMMBtu for link to delivery order schedules (e.g., 0.003413 MMMBtu/kWh).

1.2 M&V Plan Summary

Table 2. M&V Plan Summary

ECM.	ECM Description	M&V Option Used*	Summary of M&V Plan

* M&V options include A, B, C, and D. Guidelines include *M&V Guidelines: Measurement & Verification for Federal Energy Projects,* Version 2.*2* (www.eere.energy.gov/femp/financing/superespcs_mvresources.cfm); and *International Performance Measurement & Verification Protocol (IPMVP),* Volume I, March 2002 (www.ipmvp.org).

2. Whole Project Data / Global Assumptions

2.1 Risk & Responsibility

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

- Reference location of Risk & Responsibility Matrix[1] (if required).

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

2.2.1 Detail baseline energy and water rates.

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

2.3 Schedule & Reporting for Verification Activities

2.3.1 Define requirements for witnessing of measurements during:

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

2.3.2 Define schedule of verification reporting activities.

Table 3. Schedule of Verification Reporting Activities

Item	[a]Recommended time of submission	[a]Owner's review and acceptance period
Post-Installation Report	30 to 60 days after acceptance	30 days
Annual Report	30 to 60 days after annual performance period	30 days

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

[1] The Risk/Responsibility Matrix can be found in the appendix of the GEO M&V Guidelines for Energy Saving Performance Contracts

2.3.3 Define content and format of reports (as applicable):

- Post-installation report.

  Use Post-Installation Report Outline[1].

- Annual M&V reports.

  Use Annual Report Outline[1].

- Interval M&V reports (optional)

  Develop report outline if needed.

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

2.4.1 Define Agency and ESCO reporting requirements:

- Summarize key verification activities and reporting responsibilities of agency and ESCO on operations, preventive maintenance, repair, and replacement items from details in ECM specific M&V Plans
- Define content of reports and reporting schedule.

Note: If there is no change from the TEA, the Agency and ESCO reporting requirements can be gathered from that report.

2.5 Status of Rebates

- Include if applicable.

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

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

Note: Rebate status will be reported in the TEA and Contract as well. This is not necessary here if already denoted elsewhere.

2.6 Dispute Resolution

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

[1] Electronic copies of *Post-Installation Report Outline* and *Annual Report Outline* are available in the GEO M&V Guidelines for Energy Saving Performance Contracts

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

- Develop separate section for each ECM.

3.1 Brief Description of ECM (savings summary for ECMs located in Table 4)

- Provide an overview what was done for ECM and how savings are generated.

3.2 Energy and Water Baseline Development

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

3.2.2 Describe variables affecting baseline energy or water use.

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

3.2.3 Define key system performance factors characterizing the baseline conditions.

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

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

3.2.5 Provide details of baseline data collected, including:

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

3.2.6 Provide details of baseline data analysis performed, including:

- Analysis using results of measurements
- Weather normalized regressions

- Weather data used and source of data

3.3 Proposed Energy & Water Savings Calculations and Methodology

3.3.1 Provide detailed description of analysis methodology used.

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

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

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

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

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

- Provide performance period energy and water rate adjustment factors, if different from in section 2.2.2.

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

- Summarize information in Table 4.

3.4 Operations and Maintenance and Other Cost Savings

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

- Describe how savings are generated
- Detail cost savings calculations.
- Provide performance period O&M cost savings adjustment factors, if different from in section 2.2.2.

3.4.2 Provide justification for other cost savings, if applicable.

- Describe how savings are generated.
- Detail cost savings calculations.
- Provide performance period adjustment factors, if different from in section 2.2.2.

3.5 Proposed Annual Savings For ECM

Table 4. Proposed Annual Savings For ECM

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

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

Notes
*Annual electric demand savings (kW/yr) is the sum of the monthly demand savings.
** Units for fuels and water are as denoted in the bills
MMBtu = 1,000,000 Btu.
If energy is reported in units other than MMBtu, provide a conversion factor to MMBtu for link to delivery order schedules (e.g., 0.003413 MMBtu/kWh).

3.6 Post-Installation M&V Activities

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

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

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

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

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

3.6.5 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)

3.6.6 Detail data analysis to be performed.

3.7 Performance Period Verification Activities

3.7.1 Describe variables affecting performance period energy or water use.

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

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

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

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

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

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

3.7.6 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)

3.7.7 Detail data analysis to be performed.

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

- Detail verification activities and reporting responsibilities of agency and ESCO on operations, preventive maintenance, repair, and replacement items (if there is no change from the TEA, the reporting requirements can be gathered from that report).
- Define contents of report and reporting schedule, if different than in global section 2.4.

Risk – Responsibility Matrix

FINANCIAL

	Responsibility/Description
Interest rates	Neither the ESCO nor the agency has significant control over the prevailing interest rate. Until the financing is in place, interest rates will change with market conditions. Higher interest rates will increase project cost, finance term, or both. The timing of the contract signing may affect the available interest rate and project cost. Clarify when the interest rate is locked in.
Energy prices	Neither the ESCO nor the agency has significant control over actual energy prices. For calculating savings, the value of the saved energy may either be constant, change at a fixed inflation rate, or float with market conditions.
Construction costs	The ESCO is responsible for determining construction costs and defining a budget. In a fixed-price design/build contract, the agency assumes little responsibility for cost overruns. However, if construction estimates are significantly greater than originally assumed, the ESCO may find that the project or measure is no longer viable and drop it. In any design/build contract, the agency loses some design control. Clarify design standards and the design approval process (including changes) and how costs will be reviewed.
M&V Costs	The agency assumes the financial responsibility for M&V costs directly or through the ESCO. If the agency wishes to reduce M&V costs, it may do so by accepting less rigorous M&V activities with more uncertainty in the savings estimates. Clarify what performance is being guaranteed (equipment performance, operational factors, energy cost savings) and that the M&V plan is detailed enough to satisfactorily verify it.
Delays	Both the ESCO and the agency can cause delays. Failure to implement a viable project in a timely manner costs the agency in the form of lost savings and can add cost to the project. Clarify schedule and how delays will be handled.
Major changes in facility	The agency controls major changes in facility using, including closure.

OPERATIONAL

	Responsibility/Description
Operating hours	The agency generally has control over the 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 times improved efficiency of equipment vs. whole building utility analysis). Clarify if operating hours are to be measured or stipulated, and what is the impact if they change. If the operating hours are stipulated, the baseline should be carefully documented and agreed to by both parties.
Load	Equipment loads can change over time. The agency 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 if equipment loads are to be measured or stipulated and what is the impact if they change. If the equipment loads are stipulated, the baseline should be carefully documented and agreed to by both parties.

Weather	A number of energy efficiency measures are affected by weather. Neither the ESCO nor the agency has control over the weather. Changes in weather can increase or decrease "savings" depending on the M&V method (e.g., equipment run hours times efficiency improvement vs. whole building utility analysis). If weather is "normalized", actual savings could be less than payments for a given year, but will "average out" over the long run. Weather corrections to the baseline or ongoing performance should be clearly specified and understood.
Life of equipment	Equipment life is dependent on the original selection (contractor controlled) and operations and maintenance. Warranties usually cover failures in the first year. Extended warranties (often tied to service contracts) are available and assure that the agency won't continue paying for equipment that is no longer functional. Clarify who is responsible for repair and replacement of failed components throughout the term of the contract.
Agency participation	Many energy conservation measures require agency participation to generate savings (e.g., control settings). The savings can be variable and the ESCO may be unwilling to invest in these measures. Clarify what degree of agency participation is needed and utilize monitoring and training to mitigate risk. If performance is stipulated, document and review assumptions carefully and consider M&V to confirm the capacity to save (e.g., confirm that the controls are functional).

PERFORMANCE

	Responsibility/Description
Equipment performance	Generally the ESCO has control over the selection of equipment and is responsible for its proper installation and performance. Generally the ESCO has responsibility to demonstrate that the new improvements meet expected performance levels, including 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.
Maintenance	Responsibility for maintenance is negotiable; however, it is often tied to performance. Clarify how long-term maintenance will be assured, especially if the party responsible for long-term performance is not responsible for maintenance.
Operation	Responsibility for operation is negotiable and it can impact performance. Clarify how proper operation will be assured. Clarify responsibility for operations and implications of equipment control.

Post-Installation Report Outline

Adopted from DOE's Federal Energy Management Program

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

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

Performance Period Dates Covered: ___________ to_____________

1. Executive Summary

1.1 Project Background

1.1.1 Provide an overview of project background, including:

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

1.2 Brief Project and ECM Descriptions

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

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

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

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

1.3.2 Summarize information in Table 1 and Table 2.

Note: Expected savings are prediction for first year based on post-installation M&V activities. Verified savings for first year of performance period will be documented in annual report. The proposed savings for each ECM are included in the M&V Plan and Savings Calculation Methods.

Table 1. Proposed Annual Savings Overview

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

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

Notes

MMBtu=1,000,000 Btu.

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

** Units for fuels and water are as denoted in the bills

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

Guaranteed cost savings for project and the proposed savings are defined in the M&V Plan and Savings Calculation Methods.

Table 2. Expected Savings Overview for First Performance Year

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

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

Notes

MMBtu=1,000,000 Btu.

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

** Units for fuels and water are as denoted in the bills

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

1.4 Energy, Water, and O&M Rate Data

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

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

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

1.5 Savings Adjustments

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

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

1.6 Status of Rebates

- Include if applicable.

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

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

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

- Develop section for each ECM.

2.1 Brief Description of ECM (savings summary for ECMs located in Table 4)

- Provide an overview what was done for ECM and how savings are generated.

2.2 Installation Verification

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

2.2.2 Provide details of energy and cost savings impact from changes between Final Proposal (including any relevant delivery order modifications) and as-built conditions based on post-installation M&V results. Summarize information in Table 4.

Table 4. Impact to energy and cost savings from changes between final proposal and as-built conditions for ECM

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

Notes
MMBtu = 1,000,000 Btu.
*Annual electric demand savings (kW/yr) is the sum of the monthly demand savings.
** Units for fuels and water are as denoted in the bills
If energy is reported in units other than MMBtu, provide a conversion factor to MMBtu for link to delivery order schedules (e.g. 0.003413 MMBtu/kWh).

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

2.3 Post-Installation M&V Activities Conducted

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

2.3.1 Measurement equipment used

2.3.2 Equipment calibration documentation

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

2.3.4 Details to confirm adherence to sampling plan

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

2.3.6 Describe how performance criteria have been met.

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

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

2.4 Expected Savings Calculations and Methodology

2.4.1 Provide detailed description of analysis methodology used.

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

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

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

2.4.4 Details of any baseline or savings adjustments made.

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

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

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

- Summarize information in Table 5.

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

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

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

2.5.2 Describe source of other savings, if applicable.

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

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

Table 5. Expected Year 1 Savings for ECM

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

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

Notes
MMBtu = 1,000,000 Btu.
*Annual electric demand savings (kW/yr) is the sum of the monthly demand savings.
** Units for fuels and water are as denoted in the bills
If energy is reported in units other than MMBtu, provide a conversion factor to MMBtu for link to delivery order schedules (e.g. 0.003413 MMBtu/kWh).

Annual Report Outline

Adopted from DOE's Federal Energy Management Program

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

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

Performance Period Dates Covered: ___________ to_____________

Contract year #: ___________

1. Executive Summary

1.1 Project Background

1.1.1 Provide an overview of project background, including:

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

1.2 Brief Project and ECM Descriptions

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

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

1.3 Summary of Proposed and Verified Energy and Cost Savings

1.3.1 Compare verified savings for Performance Year # to Guaranteed Cost Savings for Year #. State whether guarantee is fulfilled for year. If not, provide detailed explanation.

1.3.2 Define performance period.

1.3.3 Summarize information in Table 1 and Table 2.

Table 1. Proposed Annual Savings Overview

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

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

Notes
MMBtu = 1,000,000 Btu.
*Annual electric demand savings (kW/yr) is the sum of the monthly demand savings.
** Units for fuels and water are as denoted in the bills
If energy is reported in units other than MMBtu, provide a conversion factor to MMBtu for link to delivery order schedules (e.g., 0.003413 MMBtu/kWh).
Guaranteed cost savings and the proposed savings for each ECM are included in the M&V Plan and Savings Calculation Methods.

Table 2. Verified Savings for Performance Year [#]

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

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

Notes
MMBtu = 1,000,000 Btu.
*Annual electric demand savings (kW/yr) is the sum of the monthly demand savings.
** Units for fuels and water are as denoted in the bills
If energy is reported in units other than MMBtu, provide a conversion factor to MMBtu for link to delivery order schedules (e.g. 0.003413 MMBtu/kWh).

1.4 Savings Adjustments

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

1.5 Performance and O&M Issues

- Note impact of operating deficiencies or enhancements on generation of savings.
- Note impact of maintenance deficiencies on generation of savings.
- Detail any deficiencies that need to be addressed by ESCO or Agency.

1.6 Energy, Water, and O&M Rate Data

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

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

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

1.7 Verified Savings To Date

- Summarize information in Table 3.

Table 3. Verified Savings for Performance Period To Date

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

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

Notes

MMBtu = 1,000,000 Btu.

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

** Units for fuels and water are as denoted in the bills

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

2. Details for ECM [name / #]

- Develop section for each ECM.

2.1 Brief Description of ECM (savings summary for ECMs located in Table 4)

- Provide an overview what was done for ECM and how savings are generated.

2.2 M&V Activities Conducted This Period

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

2.2.1 Measurement equipment used

2.2.2 Equipment calibration documentation

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

2.2.4 Details to confirm adherence to sampling plan

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

2.2.6 Describe how performance criteria have been met.

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

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

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 Details of any baseline or savings adjustments made.

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

- Provide performance period energy & water rate adjustment factors, if used.

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

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

- Include Table 4.

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

2.4.1 Describe source of savings, if applicable.

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

2.4.1 Describe source of other savings, if applicable.

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

Table 4. Verified Annual Savings For ECM for Performance Year #

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

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

<u>Notes</u>
MMBtu = 1,000,000 Btu.
*Annual electric demand savings (kW/yr) is the sum of the monthly demand savings.
** Units for fuels and water are as denoted in the bills
If energy is reported in units other than MMBtu, provide a conversion factor to MMBtu for link to cost schedules (e.g., 0.003413 MMBtu/kWh).

2.5 O&M and Other Activities

2.5.1 Operating requirements:

- State organization(s) responsible for equipment operations. If appropriate, detail how responsibilities are shared.
- Summarize key operating procedures and any related verification activities.
- Detail any deficiencies that need to be addressed by ESCO or Agency.
- Note impact of operating deficiencies or enhancements on generation of savings.

2.5.2 Preventive maintenance requirements:

- State organization(s) responsible for performing maintenance. If appropriate, detail how responsibilities are shared.
- Verification of scheduled maintenance items completed by ESCO or Agency.
- Detail any deficiencies that need to be addressed by ESCO or Agency.
- Note impact of maintenance deficiencies on generation of savings.

2.5.3 Repair and replacement requirements:

- State organization(s) responsible for repair and replacement. If appropriate, detail how responsibilities are shared.
- Summary of activities conducted this period by ESCO or Agency.
- Detail any deficiencies that need to be addressed by ESCO or Agency.
- Note impact of equipment deficiencies on generation of savings.