State of Wyoming

Wyoming Energy Conservation Improvement Program

For State Agencies, County & Municipal Governments, Higher Education Facilities, Public School Districts, Hospitals, and other Public Entities

PROGRAM MANUAL

Appendix 1K

WYECIP CONTRACT ATTACHMENT F MEASUREMENT and VERIFICATION PLAN GUIDELINES

APPENDIX 1K – WYECIP CONTRACT ATTACHMENT F

Attachment F
Guidelines for Measurement and Verification of Savings in Energy Performance Contracts

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. Under the Wyoming Energy Conservation Improvement Program (WYECIP), a savings guarantee is required for the entire term of a performance contract.

   There are many reasons to use measurement & verification strategies that go far beyond satisfying the requirements of the WYECIP. Properly applied, measurement & verification can:

   - Accurately assess energy savings for a project.
   - Allocate risks to the appropriate parties.
   - Reduce uncertainties to reasonable levels.
   - Ensure that the Facility Owner achieves utility budget savings.
   - Monitor equipment performance.
   - Find additional savings.
   - Improve operations & maintenance.
   - Verify savings guarantee is met.
   - Allow for future adjustments, as needed.

2. **Energy Savings Depend on Performance and Usage.** 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, both performance and usage factors need to be known to determine energy consumption and savings.

   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.

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 x operating hours.

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 x ton/hours].

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 Facility Owner's priorities and preferences. In performance contracts, risks are allocated between the ESCo and the Facility Owner. 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 Facility Owners 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 Facility Owner's control such as lighting operating hours and thermostat setpoints are typically stipulated. Using stipulations means that the ESCo and Facility Owner 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 stipulated values are used and savings are verified based entirely on measurements, then more of the risk resides with the ESCo, who must show that the guaranteed savings are realized, or prove how contributing factors affected the result. Alternatively, the Facility Owner assumes the risk for the parameters that are stipulated. In the event that the stipulated values overstate the savings, the Facility Owner will not be able to claim the actual shortfall from the ESCo's guarantee. If the actual savings are greater than expected due to underestimated stipulated values, the Facility Owner 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 Facility Owner generally assumes responsibility for usage risk by either allowing baseline adjustments based on measurements, or by agreeing to stipulated 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 stipulations in savings estimates can be a practical, cost-effective way to minimize M&V costs and allocate risks. Stipulations used appropriately do not jeopardize the savings guarantee, the Facility Owner's ability to pay for the project, or the value of the project to the government. However, stipulations shift risk to the Facility Owner, and the Facility Owner should thoroughly understand the potential consequences before accepting them. Risk is minimized through carefully crafted M&V requirements including diligent estimation of the stipulated values.

4. Primary Steps to Verify Savings.

Regardless of the M&V strategy used, similar steps are taken to verify the potential for the installed energy conservation measures (ECMs) to generate savings. Verifying the potential to generate savings can also be stated as confirming that:

Step 1: The baseline conditions were accurately defined;
Step 2: A suitable project specific M&V plan was developed;
Step 3: Proper equipment/systems were installed and are performing to specifications; and
Step 4: The equipment/systems continue to have the potential to generate the predicted savings.

These 4 steps are discussed in detail below.

4.1. Step 1: Define The Baseline.

4.1.1. Typically the ESCo defines the baseline as part of an Investment Grade Audit. Baseline physical conditions (such as equipment inventory and conditions, occupancy, nameplate data, energy consumption rate, control strategies, and so on) are typically determined 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 used to account for any changes that may occur during the performance period, which may require baseline energy use adjustments. It is the Facility Owner's responsibility to ensure the baseline has been properly defined.

4.1.2. In almost all cases after the measure has been installed, one cannot go back and re-evaluate the baseline since 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.

4.2. Step 2: Develop Project Specific Measurement & Verification Plan.

4.2.1. The proposed M&V approach is developed during the Investment Grade Audit and Project Development Phase. Although the final M&V plan is usually developed during contract negotiations, it is important that the Facility Owner and the ESCo agree upon general M&V approaches to be used prior to starting the Investment Grade Audit. The M&V method(s) chosen can have a dramatic affect on how the baseline is defined, determining what activities are conducted during the audit.

4.2.2. The final project-specific M&V plan is developed during negotiations for the Energy Performance Contract, based upon the methodologies proposed following the Investment Grade Audit. The final M&V Plan then becomes part of the contractual obligations for the ESCo and the Facility Owner for the duration of the Energy Performance Contract. The M&V plan is the single most important item in an energy savings guarantee.

4.2.3. The project specific M&V plan includes project-wide items as well as details for each ECM. Details on requirements for M&V Plans and Reports are included in the WYECIP Program Manual. In general these include:

4.2.3.1. Details of baseline conditions and data collected.

4.2.3.2. Documentation of all assumptions and sources of data.

4.2.3.3. What will be verified.

4.2.3.4. Responsibilities for conducting the M&V activities.

4.2.3.5. Schedule for all M&V activities.

4.2.3.6. Discussion on risk and savings uncertainty.

4.2.3.7. Details of engineering analysis performed.

4.2.3.8. Detail baseline energy and water rates.

4.2.3.9. Performance period adjustment factors for energy, water, and O&M rates, if used. (See note 1.)

4.2.3.10. Methodology for energy and cost savings calculations.

4.2.3.11. Details of any operations & maintenance (O&M) cost savings claimed.

4.2.3.12. Definition of O&M reporting responsibilities.

4.2.3.13. Definition of and format of all M&V reports (Post-Implementation, Commissioning and M&V, Annual or periodic).

4.2.3.14. Discussion of how & why the baseline may be adjusted.

4.2.3.15. Definition of preventive maintenance responsibilities.

The format of M&V Plans and Reports included in the Investment Grade Audit shall follow the requirements detailed in the WYECIP Program Manual.

4.3. Step 3: Post-Installation Verification.

4.3.1. Post-Implementation verification is conducted by both the ESCo and the Facility Owner to ensure that proper equipment/systems were installed, are operating correctly, and have the potential to generate the predicted savings. The verification is accomplished through commissioning and M&V activities.

4.3.2. Commissioning of installed equipment and systems is required by the WYECIP. 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 regardless of energy impact. Commissioning is generally completed by the ESCo and witnessed by the Facility Owner. In some cases, however, it is contracted out to a third party.

4.3.3. After system start-up and commissioning activities are completed, the acceptance testing and M&V activities specified in the contract are implemented. Verification methods may include surveys, inspections, spot measurements, and short-term metering.

4.3.4. The results of the commissioning and M&V activities are usually presented in reports delivered by the ESCo prior to final project acceptance, as discussed in Section 5 below.

4.4. Step 4: Periodic Performance Period Verification.

4.4.1. For the entire term of the Performance Contract, the ESCo is required to submit an annual 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.

4.4.2. 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.

4.4.3. At the end of each performance year (as specified in the contract), the ESCo shall submit an Annual Measurement and Verification Report to demonstrate that the savings have occurred. For WYECIP projects, the overall savings guarantee must be met on a cumulative basis for all ECMs. Savings for each ECM should also be itemized. The Annual Measurement and Verification Reports shall follow the requirements detailed in the WYECIP Program Manual. In general these will include:

4.4.3.1. Results/documentation of performance measurements and inspections.

4.4.3.2. Realized savings for the year (energy, energy costs, O&M costs, other).

4.4.3.3. Comparison of actual savings to the guaranteed amounts.

4.4.3.4. Details of all analysis and savings calculations, including commodity rates used and any baseline adjustments performed.

4.4.3.5. Summary of operations and maintenance activities conducted.

4.4.3.6. Details of any performance or O&M issues that require attention.

5. Post-Implementation and Commissioning Reports.

5.1. The results of the installation verification activities are presented in a Post-Implementation Report delivered by the ESCo to the Facility Owner prior to final project acceptance. This report also documents any changes in the contracted project scope and energy savings based on the actual installed conditions. The commissioning report is a separate report that details the commissioning activities conducted to assure equipment was properly installed and is operating to specification.

5.2. For projects using any stipulated values to calculate energy savings, the post-installation verification is the most important M&V step since any measurements to substantiate the savings guarantee are made only once. (See note 3.)

Thereafter, inspections may be conducted to verify that the ‘potential to perform’ exists.

5.3. The Post-Implementation Report shall follow the requirements detailed in the WYECIP Program Manual. In general these will include:

5.3.1. Project description.

5.3.2. Installation verification and list of installed equipment.

5.3.3. Details of any changes between Contract and as-built conditions, including energy impacts.

5.3.4. Documentation of all post-install verification activities and performance measurements conducted.

5.3.5. Performance verification describing how performance criteria were met.

5.3.6. Expected savings for the first year.

5.4. The Commissioning Report shall include:

5.4.1. Commissioning results and documentation.

6. 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* (IPMVP, 2001), FEMP *M&V Guidelines: Measurement and Verification for Federal Energy Projects* Version 2.2 (2000), and ASHRAE *Guideline 14: Measurement of Energy and Demand Savings* (2002).

Many industry professionals consider the *International Performance Measurement & Verification Protocol* (IPMVP) the standard protocol for conducting M&V on energy saving projects. IPMVP is available through http://ipmvp.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.

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. Options A and B are retrofit isolation methods

Whole facility methods consider only the total energy use while ignoring specific equipment performance. 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 1.

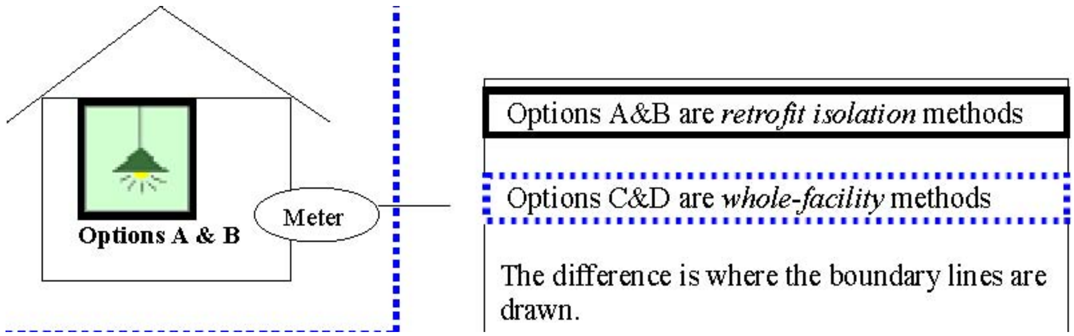

Figure 1: Retrofit Isolation vs. Whole-Facility M&V Methods

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 Facility Owner. 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.

6.1. Option A – Partially Measured Retrofit Isolation.

6.1.1. Option A is a retrofit isolation 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. Post-installation energy use, equipment performance, and usage are NOT measured throughout the term of the contract. Post-installation and baseline energy use is estimated using an engineering analysis of information that does not involve long-term measurements.

6.1.2. 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 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.

6.1.3. 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 small percentage of overall cost savings.

6.1.4. Additional information on the proper application of Option A methods are discussed in *Detailed Guidelines for FEMP M&V Option A* available through http://ateam.lbl.gov/mv/docs/OptionADetailedGuidelines.pdf.

6.2. Option B – Retrofit Isolation.

6.2.1. Option B is a retrofit isolation or system level approach, and requires continuous measurement 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. 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.

6.2.2. 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.

6.2.3. Option B methods are appropriate for complex systems whose load or operating conditions are not well know or are highly dependent on external factors. Examples of projects where Option B may be appropriate include variable frequency drive installations, modifications to control systems, chiller system upgrades, or measures with high percentage of overall cost savings.

6.3. Option C – Whole Facility Energy Use.

6.3.1. Option C is a whole-building verification method. Savings are based on actual energy consumption as measured by the utility meter(s) and/or regression modeling. Estimated savings will vary over the contract term.

6.3.2. 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 and determine savings.

6.3.3. 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.

6.3.4. 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.

6.4. Option D – Calibrated Simulation.

6.4.1. 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.

6.4.2. Option D uses calibrated computer simulation models of component or whole-building energy consumption to determine energy savings. Linking simulation inputs to baseline and post-installation conditions completes the calibration, and may involve metering performance and operating factors before and after the retrofit. Specialized software packages, such as DOE-2, are used in Option D and the development of accurate building models requires substantial time and expertise.

6.4.3. 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.

7. 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, and chiller replacements.

7.1. Lighting Upgrades.

7.1.1. **Option A.**

7.1.1.1. Measure operating hours for duration of 2 – 3 weeks during audit phase, during non-holiday timeframe. Use sampling plan with 80 / 20 confidence / precision (11 samples per group).

7.1.1.2. If hours of operation are well documented and stable, then conservative stipulated hours are acceptable if backed up with some monitoring during the audit.

7.1.1.3. Fixture powers based on standard tables (utility or EPRI lighting tables) only if inventory of equipment is very accurate (including lamp & ballast types)

7.1.1.3.1. Measure power of unknown or unusual fixture types.

7.1.1.4. Use diversity factor to determine demand reduction (% lights on during utility peak)

7.1.1.5. Heating penalty, cooling bonus are allowable where appropriate.

7.1.1.6. Provide detailed calculation methodologies.

7.2. Variable Speed Drives

7.2.1. Option B

7.2.1.1. Baseline operating hours should be measured. Baseline power should be measured; spot measurements acceptable for constant loads

7.2.1.2. Post-retrofit operating hours and power (or speed) should be continuously measured (by EMCS), since demand savings are not guaranteed with VSDs (100% speed = 100% load). Adjust the baseline for actual use conditions if needed.

7.3. Constant Speed Motors

7.3.1. Option A

7.3.1.1. Baseline operating hours should be measured. If hours of operation predictable (i.e. 24 hrs/day), stipulate post-retrofit operating hours. If hours of operation are variable or change, measure post-retrofit motor runtime.

7.3.1.2. Measure baseline and post retrofit motor powers (depends on load factor, which vary), spot measurements okay for constant loads.

7.4. Water Measures

7.4.1. **Option C**

7.4.1.1. If metering exists and usage is being affected by more than 20% then use Option C.

7.4.1.2. Establish statistically significant relationship between use and dependent factors (weather, occupancy and/or other use factors) using regression analysis during audit (R2 >0.8). Adjust baseline using post-retrofit conditions or normalize post-retrofit data to typical year data.

7.4.2. **Option A (Use if Option C is not applicable.)**

7.4.2.1. Assume consumption (i.e. flushes/day) and ensure water consumption model accounts for no more than 75% of the water bill (result is conservative load assumptions).

7.4.2.2. 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%)

7.5. Controls Measures

7.5.1. **Option B**

7.5.1.1. Baseline conditions should be verified through short-term measurements (i.e. document operating hours; demonstrate no economizer or reset).

7.5.1.2. 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.

7.5.1.3. Monthly monitoring of data collection recommended.

7.6. Boiler Replacement

7.6.1. **Option C**

7.6.1.1. Savings should exceed 20% of metered usage.

7.6.1.2. Establish a statistically significant relationship between utility use and weather and/or other dependent factors (occupancy and/or other use factors) using regression analysis during audit (R2 >0.8).

7.6.1.3. 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.

7.6.2. Option A/B (Use if Option C is not applicable).

7.6.2.1. Operating hours and load should be measured and verified with analysis of utility data.

7.6.2.2. Baseline combustion efficiency should be measured. Post-retrofit combustion efficiency should be measured every year.

7.6.2.3. Establish relationship between use and weather and/or other dependent factors using regression analysis during audit. Adjust baseline using actual weather or normalize post-retrofit data to typical year weather data.

7.7. Chiller Replacement.

7.7.1. **Option**

7.7.1.1. Range of baseline efficiencies should be determined through measurements (kW/ton). If baseline efficiency is stipulated, the original (un-degraded) equipment efficiency should be used.

7.7.1.2. Use measured data to develop regression for weather vs. load. Post-retrofit: continuously measure load and energy use. Apply baseline efficiency to measured load data to determine savings.

7.7.1.3. Adjust baseline using actual weather or normalize post-retrofit data to typical year weather data.

8. Notes:

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

8.2. FEMP M&V Guidelines and Outlines are available through http://www.eere.energy.gov/femp/financing/superespcs_mvresources.cfm.

8.3. Using stipulations means that the ESCo and Facility Owner agree to use a set value for a parameter throughout the term of the contract, regardless of the actual behavior of that parameter.