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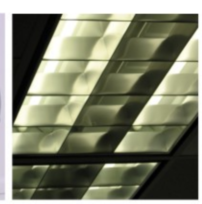
GUIDE

Measurement & Verification Of Energy Efficiency Projects








January 2007

Measurement & Verification

Of Energy Efficiency Projects

Guidelines

Contents

BASIC CONCEPTS

Any organization contracting for large energy efficiency projects should be familiar with the **International Performance Measurement and Verification Protocol** (IPMVP). IPMVP provides guidance for measuring the savings produced by energy efficiency initiatives. It is a compilation of best industry practices for determining the degree to which efficiency measures produce savings. Although the word "large" is a relative term, for many organizations that is probably going to mean projects that cost over $100,000. Information on IPMVP is easy to obtain. You can down load a free copy from their web site at: http://www.ipmvp.org.

What is IPMVP?

The IPMVP is maintained with the sponsorship of the US Department of Energy by a broad international coalition of facility owners/operators, financiers, contractors or Energy Services Companies (ESCOs) and other stake holders. Energy conservation measures covered by the IPMVP include fuel saving measures, water efficiency measures, load shifting and energy reductions through installation or retrofit of equipment, and/or modification of operating procedures.

The IPMVP Committee is now the **Efficiency Valuation Organization**, a non-profit organization, which develops products and services to aid in:

- The measurement and verification (M&V) of energy and water savings resulting from energy/water efficiency projects - both retrofits and new construction.
- Financial risk management of energy savings performance contracts
- Quantifying emissions reductions from energy efficiency projects
- Promoting sustainable and green construction through cost-effective and accurate accounting of energy and water savings.

"How can I be sure I'm really saving money?"

The purpose of IPMVP is to answer this question. IPMVP provides a "framework to determine energy and water savings resulting from the implementation of an energy efficiency program." The framework provided by IPMVP has become the industry standard for savings verification. This guide focuses on *Volume I, Concepts and Options for Determining Energy and Water Savings*. Other volumes address the subjects of monitoring the performance of renewable energy systems and enhancing indoor environmental quality in buildings.

According to the IPMVP, it provides "an overview of current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects." Volume I addresses energy conservation measures that reduce energy through the installation or retrofit of equipment or the modification of operating procedures.

Because energy consumption and costs are often "invisible" to all but a very few in any given organization, a very important question arises when considering energy efficiency projects, "how can we know what we are really saving?" Large energy efficiency contracts should include at least some of the elements recommended in the IPMVP. Often these contracts include a savings guarantee that pays for part or all of the costs of the project. The IPMVP provides a very credible guidance to help the project administrator verify that savings have occurred and how much has been realized.

Why Measurement and Verification?

The question noted above, "How can I be sure I'm really saving money," essentially addresses the risk of non-performance of the energy efficiency measure. Because measurement and verification can be costly, it is important to match the M&V strategy to the level of risk. Therefore, it is not necessarily a dollar threshold as indicated above (e.g. greater than $100,000). It depends on other factors that relate to the risk of non-performance. If the risk of non-performance is deemed low, then the effort expended toward measurement and verification may be small. ***Appendix A*** lists a number of factors that might be considered when determining the level and intensity of M&V strategies.

Key Points

According to *Environmental Energy Technologies News*, Lawrence Berkeley National Laboratory, "use of IPMVP has become standard in almost all energy efficiency projects where payments to the contractors are based on the energy savings that will result from the implementation of a variety of energy conservation measures (ECM's). IPMVP has been translated into ten languages. More than 300 professionals from 100 U.S. and international organizations have contributed thousands of hours on a completely voluntary basis to update and revise IPMVP." Although the volume is large and somewhat technical there are several sections that project administrators should be familiar with.

- Savings Measurement
- Measurement Options
- The Measurement & Verification Plan
- Third Party Verification
- Valuation of units of utility resource savings

Savings Measurement

There is a very simple formula for measuring savings:

Energy Savings = Base Year Energy Use – Post Retrofit Energy Use + or – Adjustments

It is very important to understand where these numbers come from and especially how adjustments will be applied. Adjustments are made in order to more realistically compare post retrofit conditions to the base year conditions (significant changes in square feet, weather differences, operational hours, and the addition of other loads that did not exist during the base year). If these factors were not accounted for, it is possible that savings would be improperly calculated too low or too high. The use of adjustment factors yields savings that are often referred to as "avoided" energy use of the post retrofit period.

Measurement Options

There are four approaches to measuring savings that are termed "Options A, B, C, and D." These are the cornerstones of the standardized set of procedures contained in the IPMVP. This group of options can be divided in to two main categories.

Options A and B (Isolation Retrofit Approach)

Options A and B focus on the performance of specific ECM's such as items of equipment and installed retrofits that can be measured in isolation from the rest of the building. Before and after measurements are taken and compared to determine the savings. A lighting retrofit is a good example for Option A. Installation of variable speed drives is a good example for Option B.

Options C and D (Whole Building Approach)
These options are used when the nature of the ECM is not easily measured in isolation from the rest of the building operations. This could be typical of operational and control changes that affect many areas of the building. The Option C approach assesses savings at the whole-facility level by analyzing utility bills before and after the implementation of the ECM's. Option D uses computer simulations and modeling of the whole facility, usually when base year energy data is not available or reliable. Installation of energy management control systems (EMS) and training/awareness programs are good examples for Option C. Generally, Options C and D involve much more time and skill to conduct and, therefore, are going to be more costly measurement approaches.

Measurement and Verification (M&V) Plan

According to the IPMVP, "an M&V Plan is central to proper savings determination and the basis for verification." The M&V Plan "fundamentally defines the meaning of the word 'savings' for each project" and should include the following elements:

- A description of the ECM and its intended result
- An overview of the intended IPMVP option to be used that applies to the ECM's to be employed, documentation of pre-ECM or base year operating data, design of the energy savings program, and the boundaries of the savings determination
- Measurement methods and equipment to be used
- Commissioning of the newly installed ECM's
- Documentation of post ECM energy and operating data
- Savings report
- Costs of M&V operations and equipment

The IPMVP provides an extensive list of other elements to be included in an M&V Plan depending on the nature of the project.

Third Party Verification
According to the IPMVP, "where the firm performing the energy savings determination has more experience than the owner, the owner may seek assistance in reviewing savings reports." This should begin at the time that the M&V plan is being developed.

This is especially important for contracts where a guarantee of savings has been included so that both parties believe the information that determines the payments is valid and accurate.

Valuation of Units of Utility Resource Savings or Avoidance

The IPMVP section that relates to Energy Prices is quoted in its entirety:

> "Energy cost savings may be calculated by applying the price of each energy or demand unit to the determined savings. The price of energy should be the energy provider's rate schedule or an appropriate simplification thereof. Appropriate simplifications use marginal prices which

> consider all aspects of billing affected by metered amounts, such as consumption charges, demand charges, transformer credits, power factor, demand ratchets, early payment discounts."

It is highly advisable that you do not permit the use of "average unit costs" (also known as "blended rates," or "effective rates") for energy savings, as you will run the risk of significantly over stating actual savings. Use of average unit costs is appropriate for developing utility cost projections, utility budgets, and as a key indicator for monitoring energy costs. However, it is too simplistic for use in verifying savings and does not account for important variables that determine what is actually saved.

Measurement or Stipulation

Measurements are used to verify equipment operation and demonstrate that savings can be achieved. Typically, only one or two sets of measurements are made and the results are applied to the project for the contract term. One measurement is made if the parameter (or relationship) in question is not expected to change following installation; two measurements are made before and after installation if that parameter is expected to change following installation. In place of measurements, some of the values (or relationships) upon which the savings are based may be estimated and then *stipulated*. Once agreed to by all parties, they will be held constant for the duration of the project or contract term.

To *stipulate* a parameter is to hold its value constant regardless of what the actual value is during the contract term. A stipulation in an M&V plan is an agreement between the ESCO and agency to accept a defined value of a specific factor, such as operating hours, in determining the baseline and/or post-installation energy consumption used to calculate the guaranteed savings. Appropriate stipulations assume that the calculated value will be very close to the actual and save costs by eliminating the measurement process.

Stipulated values must be based on reliable, traceable, and documented sources of information, such as:

- Standard lighting tables from recognized sources
- Manufacturer's specifications
- Building occupancy schedules
- Maintenance logs
- Performance curves published by national organizations
- Weather data from government agencies

Sources of stipulated values must be documented in the M&V plan. Even when stipulated values are used in place of measurements, periodically verifying equipment performance (technically, the *potential to perform*) should still be accomplished.

Allocating 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 energy performance contracts, risks are allocated between the energy services company (ESCO) and the 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 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 lighting operating hours and thermostat setpoints are typically stipulated.

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 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 ESCO's guarantee. If the actual savings are greater than expected due to underestimated stipulated values, 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 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 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 including diligent estimation of the stipulated values.

Measuring 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, 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.

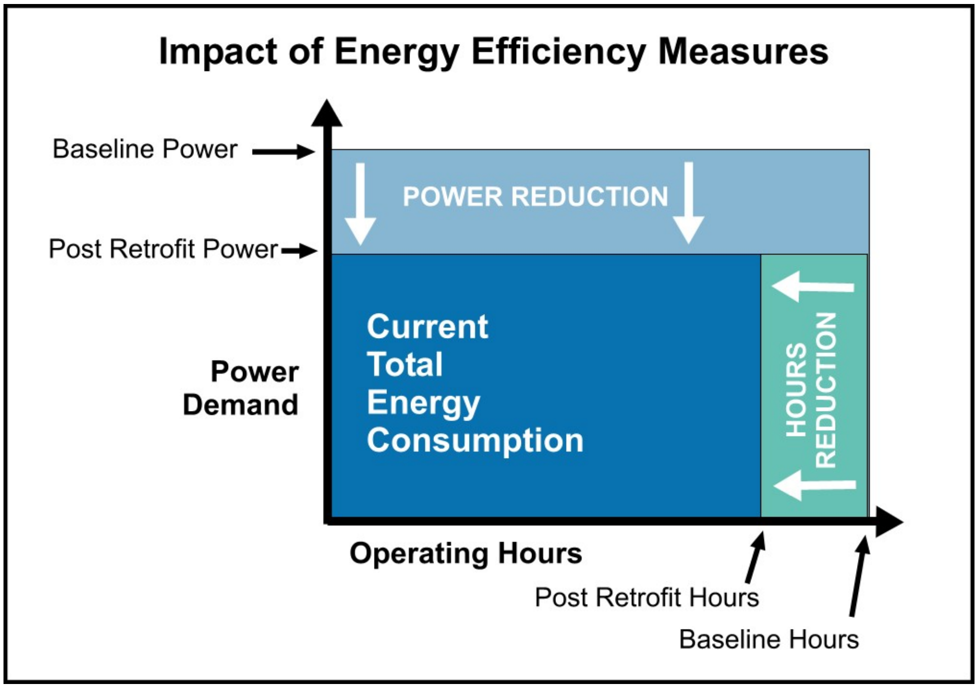


Figure 1: Energy Savings Depend on Performance and Usage

Both performance and usage factors need to be known to determine energy consumption and savings, as shown in Figure 1. Lighting provides a simple example: performance (power demand) 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 (power) times 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].

The Process

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 specification, and

Step 4: The equipment/systems continue to have the potential to generate the predicted savings.

<u>Step 1: Define The Baseline</u>

Typically the ESCO defines the baseline as part of a Technical Energy 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 agency's responsibility to ensure the baseline has been properly defined.

In almost all cases after the measure has been installed, 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.

Step 2: Develop Project Specific Measurement & Verification Plan

The project specific M&V plan is developed during contract negotiations. The M&V plan is the single most important item in an energy savings "guarantee."

The project specific M&V plan includes project-wide items as well as details for each ECM, including:

- Details of baseline conditions and data collected
- Documentation of all assumptions and sources of data
- What will be verified
- Who will conduct the M&V activities
- Schedule for all M&V activities
- Discussion on risk and savings uncertainty
- Details of engineering analysis performed
- Detail baseline energy and water rates.
- Provide performance period adjustment factors for energy, water, and O&M rates, if used[1].
- How energy and cost savings will be calculated
- Detail any operations & maintenance (O&M) cost savings claimed
- Define O&M reporting responsibilities
- Define content and format of all M&V reports (Post-Installation Commissioning and M&V, Annual or periodic)
- How & why the baseline may be adjusted
- Define preventive maintenance responsibilities

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 Technical Energy 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.

It is strongly recommended that the format of M&V plan included in the Technical Energy Audit follows the Annual Report Outline[2] developed by FEMP.

[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.

Step 3: Post-Installation Verification

Post-installation verification is 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 is accomplished through commissioning and M&V activities.

Commissioning of installed equipment and systems should be required. 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 agency. In some cases, however, it is contracted out to a third party.

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

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 below.

Post-Installation and Commissioning Reports

The results of the installation verification activities are presented in a Post-Installation Report delivered by the ESCO to the agency 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 details the commissioning activities conducted to assure equipment was properly installed and is operating to specification.

For projects using any stipulated values[3] 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. Thereafter, inspections may be conducted to verify that the 'potential to perform' exists.

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
- Expected savings for the first year

The Commissioning Report includes:

- results
- documentation

It is strongly recommended that the format of the Post-Installation Report follows the Post-Installation Report Outline[4] developed by FEMP.

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[2] FEMP M&V Outlines are available through http://www.eere.energy.gov/femp/financing/superespcs_mvresources.cfm.

[3] 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.

Step 4: Periodic Performance Period Verification

For at least the first two or three years after installation, the ESCO should be required to submit an annual report documenting the savings actually achieved. Some states already have statutes governing this requirement. 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. 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 contract), the contractor submits an Annual Performance Report to demonstrate that the savings have occurred. Each State will have its own requirements for how the overall savings guarantee has to be met on a cumulative basis for all ECMs. It is appropriate, however, to itemize the 'actual' savings for each ECM.

The Annual Performance Reports should include:

- 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

FEMP has a very helpful format for the Annual Report Outline[5].

The Measurement & Verification Plan

The development of an M&V plan should begin early in the project development phase. Each energy conservation measure should be addressed in the plan. You may find it necessary to drop or ignore savings associated with certain measures because the savings are either not measurable or would be too costly to measure. There are many factors to consider when choosing the method of measurement.

- Cost of measurement vs. savings
- Timing of measure installation
- Likelihood of future ECMs at the same facility
- Likelihood of future construction at the facility
- Degree of submetering within the facility
- Complexity of ECMs to be installed

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[4] FEMP M&V Outlines are available through http://www.eere.energy.gov/femp/financing/superespcs_mvresources.cfm.

[5] FEMP M&V Outlines are available through http://www.eere.energy.gov/femp/financing/superespcs_mvresources.cfm.

- Level of interaction between ECMs
- Dynamics of the facility's historical energy baselines
- Likelihood of sustainable savings from the measures

Factors that affect cost and appropriate level of M&V include:

- Value of projected savings Complexity of efficiency equipment
- Total amount of equipment
- Number of interactive effects
- Level of uncertainty of savings Risk allocation for achieved savings between agency and ESCO
- Other valuable uses of M&V data (e.g., optimizing operations and maintenance)
- Availability and capability of an energy management system

M&V Protocols and Methods

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 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.

Option A – Partially Measured Retrofit Isolation

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.

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.

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.

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.

Option B – Retrofit Isolation

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.

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 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.

Option C – Whole Facility Energy Use

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.

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.

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.

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 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.

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.

Specific ECMs and Related Measurement Methods

Recommended M&V approaches are provided below 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.

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 (11 samples per group).
- 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 powers based on standard tables (utility or EPRI lighting tables) only if inventory of equipment is very accurate (including lamp & ballast types); Measure power of unknown or unusual fixture types.
- Use diversity factor to determine demand reduction (% lights on during utility peak)
- Heating penalty, cooling bonus are allowable where appropriate. Provide detailed calculation methodologies.

Variable Speed Drives

Option B

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

Constant Speed Motors

Option A

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

Water Measures

Option C

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

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 (result is 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%)

Controls Measures

Option B

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

Boiler Replacement

Option C

- Savings should exceed 20% of metered usage.
- 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).
- 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

- Use if Option C is not applicable.
- Operating hours and load should be measured and verified with analysis of utility data.
- Baseline combustion efficiency should be measured. 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 normalize post-retrofit data to typical year weather data.

Chiller Replacement

Option B

- Range of baseline efficiencies should be determined through measurements (kW/ton)
- If baseline efficiency is stipulated, the original (un-degradated) equipment efficiency should be used
- 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. Adjust baseline using actual weather or normalize post-retrofit data to typical year weather data.

Large Scale Behavioral Modification Programs

Option A

- If hours of operation are well documented and stable, then conservative stipulated hours are acceptable if backed up with some monitoring during the audit. Occupancy-based data loggers can be used to verify pre and post operation of a specific operational ECM.

Option B

- Baseline conditions should be verified through short-term measurements (i.e. document operating hours; equipment schedules; and Energy Management Control System (EMCS) trend logs).
- 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.

Option C

- In many cases, especially educational institutions where there is a utility meter (or a combination that can be totaled) for an entire campus, data from utility bills can be used for baseline establishment and post measure verification.
- Monthly monitoring with the use of meter data contained on utility bills. There are a number of baseline adjustment factors that should be identified early in project development.

Sample M&V Plan Section Headings

The typical contents of an M&V plan will include project level and ECM-specific elements. Below is a description of the primary elements that need to be included in an M&V plan, along with a discussion of the issues related to the allocation of performance risks and responsibilities.

Project Level Components
- Project Description and M&V Overview
- Project Savings and Costs from contract
- Schedule
- Reports to be Prepared
- Risk and Responsibility Matrix

ECM Specific M&V Components
- Measure Description
- Objectives
- Parameters to be Monitored
- Sampling Plan
- Data Collection Plan
- Pre-Installation Energy and Performance Baseline
- Post-Installation Facility Conditions
- Determination of Energy Savings
- Plan for Future Measurements
- Plan for Resolving Disputes

Appendix A
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.