M & V Guidelines for HUD Energy Performance Contracts

Guidance for ESCo-Developed Projects

1/21/2011

1) Purpose of the HUD M&V Guide

This document contains the procedures and guidelines for quantifying the savings resulting from energy efficient equipment, water conservation, renewable energy, and cogeneration projects implemented through U.S. Department of Housing and Urban Development's (HUD's) energy performance incentives as defined in 24 CFR 990.185. Federal regulations 24 CFR990.185 state that HUD may approve financial incentives for a PHA based upon a determination that payments under a contract can be funded from "reasonably anticipated energy costs". This document serves as the basis for HUD's determination of such savings.

The "performance" aspect of performance contracting refers to energy performance and drives the way in which savings are determined. Since the measurement and verification (M&V) approach calculates and documents energy savings, it is one of the most important activities associated with implementing performance contracts and is a crucial issue in contract negotiations.

2) Other M&V Guidelines

Measuring and verifying savings from performance contracting projects requires special project planning and engineering activities. Although M&V is an evolving science, industry best practices have been developed. HUD's guidance is taken directly from the Federal Energy Management Program M&V Guidelines as published in their Version 3.0, dated April 2008 and has been revised to reflect specific needs of HUD's energy performance program. Other standards recognized by HUD include the International Performance Measurement & Verification Protocol (IPMVP) and American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) 14 .standards.

3) Using M&V to Manage Risk

At the heart of a performance contract is a guarantee of specified level of performance (consumption) savings. One of the primary purposes of M&V is to reduce risk of non performance to an acceptable level, which is a subjective judgment based on HUD and PHA priorities and preferences. Within energy performance contracts, project risk and responsibilities are allocated between the Energy Service Company (ESCo), the PHA and HUD. In the context of M&V, the word "risk" refers to the uncertainty that expected consumption savings will be realized, including the potential monetary consequences.

The allocation of responsibilities between the ESCo, PHA and HUD drives the measurement and verification strategy, which actually defines the specifics of how fulfillment of the savings guarantee will be determined. All parties are reluctant to assume responsibility for factors they cannot control. The risks in achieving energy savings can be allocated between usage and performance factors.

a) Usage Risk - Risk related to usage stems from uncertainty of operational factors. For example, savings fluctuate depending on weather, occupancy levels, as well as the number of hours in which equipment is used. Because ESCos often have no control over such factors, they are usually reluctant to assume usage risk. The PHA and HUD generally assume responsibility for usage risk by either allowing baseline adjustments based on fluctuations associated with operational factors or by agreeing to stipulated equipment operating hours or other usage related factors.

b) Performance risk is the uncertainty associated with characterizing the specified level of equipment performance. The ESCo is ultimately responsible for selection, application, design, installation and performance of the equipment. Operations, preventive maintenance, repair and replacement practices can have a dramatic impact on equipment performance. The responsibilities for these practices must be clearly defined in an energy performance contract.

Stipulating certain parameters in the M&V Plan can align the responsibilities especially for the items that no one controls. Using stipulations means that the ESCo and PHA agree to employ 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 measurement, then all of the risk resides with the ESCo, which must show that the guaranteed savings are realized regardless of contributing factors. Alternately, the PHA and HUD assume the risk for the parameters that are stipulated.

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

Confidence by definition means: a state of being certain either that a hypothesis or prediction is correct or that a chosen course of action is the best or most effective.

Both the PHA and HUD assume the responsibility for determining the level of confidence that is desired in the M&V program and the energy savings determinations. The desired confidence will be reflected in the resources required for the M&V program, and the ESCo must consider the requirement prior to submittal of the final proposal.

HUD recommends that a confidence level of 80% with a precision of 10% be utilized in sampling of all stipulated savings for both performance and operational parameters. This confidence level establishes the level of risk acceptable to HUD and the PHA when stipulation parameters are used in calculating energy savings. **Exceptions to this recommendation would include:**

1. HUD's determination that the associated risks are low to the PHA and HUD.
2. HUD's determination that the M&V costs are excessive as compared to the value of the energy savings. If the costs are excessive, a confidence level of 80% with a precision of 20% should be considered.

4) Overview of M&V Options A, B, C and D.

Federal regulations 24 CFR990.185 state that HUD may approve financial incentives for a PHA based upon a determination that payments under a contract can be funded from reasonably anticipated energy costs savings. This document and the M&V methodology as defined in the Federal Energy Management Program (FEMP): M&V Guidelines, Version 3.0 dated April 2008 will serve as the basis for such approval.

These guidelines divide the M&V methodologies into four general options: Option A, B, C and D.

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 the total energy use and de-emphasize specific equipment performance.

The four FEMP M&V options that HUD will utilize are summarized in the following table. Each option has advantages and disadvantages based on site-specific factors, needs and expectations of the PHA and HUD. While each option defines an approach to determine savings, it is important to realize that savings are estimated values. **The accuracy of these estimates, however, will improve with the number and quality of the measurements made.**

M&V Option	Performance and Usage Factors	Savings Calculation
Option A Retrofit Isolation with Key Parameter Measurement	This option is based on a combination of measured and estimated factors when variations in factors are not expected. Measurements are spot or short-term and are taken at the component or system level, both in the baseline and post-installation cases. Measurements should include the key performance parameter(s) which define the energy use of the energy conservation measure (ECM). Estimated factors are supported by historical or manufacturer's data. Savings are determined by means of engineering calculations of baseline and post-installation energy use based on measured and estimated values.	Direct measurements and estimated values, engineering calculations and/or component or system models often developed through regression analysis Adjustments to models are not typically required.
Option B Retrofit Isolation with All Parameter Measurement	This option is based on periodic or continuous measurements of energy use taken at the component or system level when variations in factors are expected. Energy is measured continuously. Periodic spot or short-term measurements may suffice when variations in factors are not expected.	Direct measurements, engineering calculations, and/or component or system models often developed

	Savings are determined from analysis of baseline and reporting period energy use.	through regression analysis
Option C Utility Data Analysis	This option is based on long-term, continuous, whole-building utility meter, facility level, or sub-meter energy (or water) data. Savings are determined from analysis of baseline and reporting period energy data. Typically, a simple comparison is usually used but regression analysis may be used to adjust for independent variables.	Baseline consumption less Actual consumption times Current utility rate
Option D Calibrated Computer Simulation	Computer simulation software is used to model energy performance of a whole-facility (or sub-facility). HUD must approve the modeling software. See FEMP manual for additional guidance.	Based on computer simulation model calibrated with whole-building metered data or both. Adjustments to models are required.

5) Developing Regression Models

All M&V options utilize models to predict the baseline and performance period energy use of the project or energy conservation measure based on the behavior of the appropriate independent variable. An independent variable is a parameter that is expected to change regularly and has a measurable effect on the energy use of a system or building. The models used to predict energy use, with the exception of Option D which utilizes simulation software are often mathematical equations derived through regression analysis that incorporate the key independent variables. Regression models involve an evaluation of the energy behavior of a facility or system to determine how it relates to one or more independent variables (e.g., weather, occupancy, production rate). Regression models are a technique often used to adjust baseline or performance period energy use to account for changes in weather, occupancy, or other factors between the baseline and performance periods.

6) Independent Variables

An independent variable is a parameter that is expected to change regularly and has a measurable effect on the energy use of a system or building. Typical independent variables that drive energy consumption that can be incorporated in regression models include outdoor temperature, other weather parameters (e.g., heating or cooling degree days), occupancy, operating hours, building usage type and other variable site conditions.

Data on independent variables may be from a third party or may be tracked using onsite data collection, depending on their nature. Weather data are typically more reliable when supplied by an independent source, but should be validated with site data to ensure applicability.

Once the data have been collected, the mathematical model that is used to predict the baseline (or performance period) energy use is developed. The model should make intuitive sense—the independent variables should be reasonable and the coefficients should have the expected sign (positive or negative) and be within an expected range or magnitude

7) Documentation

All models should be thoroughly documented including specifying model limits. Ideally, the range of values of the independent variables used to create the model span the entire range of possible conditions. Models are generally good only for the range of independent variables used in creating the regression model.

The criteria used for identifying and eliminating any available data must be documented. Outliers are data beyond the expected range of values (or two to three standard deviations away from the average of the data). The elimination of outliers, however, should be justified by abnormal or specific mitigating factors. If a reason for the unexpected data cannot be found, the data should be included in the analysis. Outliers should be defined using common sense as well as common statistical practice.

8) Savings Determination

In general, the procedure for determining energy savings with a regression model is as follows:

- Develop and validate an appropriate baseline model relating the baseline energy use during normal operations to key independent variables. Calculation of this baseline is very important, as it will be used as the starting point from which to measure savings. Guidance on how to calculate an accurate baseline can be found in "Baseline Review Process: How to Establish the Utility Baseline" which can be found on the Public Housing Environment and Conservation Clearinghouse web page at www.nls.gov/offices/pih/programs/ph/phecc/eperformance.cfm.
- Install ECMs and continuously measure the independent variables used in the baseline model along with any additional variables that may be needed for performance period model development.
- Using the baseline model, estimate what the energy use would have been without the ECMs by driving the baseline model with the performance period weather or other independent variables.
- Calculate savings by comparing the predicted baseline energy use with the actual energy use of the performance period.

The best regression model is one that is simple and yet produces accurate and repeatable savings estimates. Determining the best model often requires testing several models to find one that is easy enough to use and meets statistical requirements for accuracy.

9) Option A – Retrofit Isolation with Key Parameter Measurement

M&V Option A involves a retrofit or system level M&V assessment. The approach is intended for retrofits where key performance factors or operational factors (e.g., lighting operational hours) can be spot or short-term-measured during the baseline and post-installation periods. Any factor not measured is estimated based on analysis of historical data, or manufacturer's data.

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

- Ensures that baseline conditions have been properly defined
- Confirms that the proper equipment/systems were installed and that they have the potential to generate predicted savings
- Verifies that the installed equipment/systems continue to have the capacity to yield the predicted savings during the term of the contract

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

- The magnitude of savings is low for the entire project or a portion of the project to which Option A is applied.
- The risk of not achieving savings is low.
- The independent variables that drive energy use are not difficult or expensive to measure, and are not expected to change.
- Interactive effects can be reasonably estimated or ignored
- Long-term measurements are not warranted

a) Approach to Option A

Option A is an approach designed for projects in which the potential to generate savings must be verified, but the actual savings can be determined from short-term measurements, estimates, and engineering calculations. Performance period energy use is not measured throughout the term of the contract. Performance period energy use and baseline energy use are predicted using an engineering or statistical analysis of information that does not involve long-term measurements.

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

b) Measurements

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

A key consideration in implementing Option A is identifying the parameters that will be measured and those that will be estimated. The key performance parameter(s) that the ESCo is responsible for should be measured in both the baseline and performance period cases, and savings should be calculated from these values. For example, the watts/fixture is the key performance parameter for a lighting retrofit.

Other parameters that affect energy use (e.g., operating hours) that the agency or no one controls, can be estimated and then stipulated in the contract. **Where these other parameters are not known with sufficient certainty, they should be measured in the baseline case and then stipulated.** The penalty associated with low accuracy is not achieving the estimated savings and the associated utility bill cost reductions.

c) Estimates

i) Estimates should be based on reliable, documentable sources **and should be known with a high degree of confidence.** While direct measurements from short-term logging or existing ECM records are the preferred information source, such information may not be available or may be costly to obtain. Sources of information on which estimations should be based include the following (in decreasing order of preference):

- Models derived from measurements and monitoring
- Manufacturer's data or standard tables (such as lighting tables used in utility demand-side management programs)
- Industry-accepted performance curves, such as standards published by the American National Standards Institute (ANSI), American Refrigeration Institute (ARI), and the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)
- Typical Meteorological Year (TMY) weather data
- Observations of building and occupant behavior
- Facility operations and maintenance logs

ii) Estimated parameters should not come from the following:

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

iii) Acceptable usage parameters: HUD will accept the following usage parameters in the calculation of energy savings:

Lighting Fixture Type	Usage Parameter
Living Room	4 hrs / day
Kitchen	4 hrs / day
Pantry	1 hr / day
Hall	2 hrs / day
Bathroom	3 hrs / day
Bedroom	3 hrs / day

Porch	3 hrs / day

d) Ongoing Verifications

The potential to generate savings may be verified through spot/short-term metering and inspections conducted immediately before and immediately after installation. Annual (or some other regular interval) inspections **must** be conducted as per the following table to verify that the proper equipment/systems are installed and the equipment/systems are performing to specification.

Incentive Type	Frequency of Inspections for Option A
Frozen Rolling Base & Resident Paid Utilities	• Before installation • After Installation 1st Year Every Fifth Year Note 1 Every year when savings are not achieved in the preceding year.
Add-On Subsidy	• Before installation • After Installation – Yearly
Note 1 – Variations to the M&V Plan may be approved by HUD for stipulated values that pose minimum usage risk.	

10) Option B – Retrofit Isolation with all parameters measured.

M&V Option B is a retrofit isolation or system-level approach. The approach is intended for retrofits with performance factors and operational factors (lighting operational hours) that can be measured at the component or system level and where long-term performance needs to be verified. It is similar to Option A, but uses periodic or continuous metering of all energy quantities, or all parameters needed to calculate energy, during the performance period. This approach provides the greatest accuracy in the calculation of savings, but increases the performance-period M&V cost.

11) Option C – Whole Building Data Analysis

M&V Option C involves whole-facility utility or sub-meter data analysis procedures to verify the performance of retrofit projects in which whole-facility baseline and performance period data are available. Option C usually involves collecting historical whole-facility baseline energy use and related data and continuously measuring whole-facility energy use after ECM installation. Baseline and periodic inspections of the equipment are also needed. Energy savings under Option C are by developing statistically representative models of whole-facility or sub-metered energy consumption. This method confirms total energy savings, but does not measure the savings from individual components. A simple calculation for energy savings assuming that all variables are constant is:

> Energy Savings = Utility consumption before the improvement *less* the Utility consumption after the improvement *times* the current utility rate.

In general, Option C should be used:

1. When estimated savings, by utility, are greater than 15% of the site's utility cost; and
2. When the M&V costs by utility by project do not exceed 40% of the annual energy savings

12) Option D – Calibrated Simulation

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

The use of Option D will be limited to:

1. When new construction projects are involved.
2. When Option A, B or C tools cannot cost-effectively evaluate particular measures.

13) Mathematical Methods for Sampling

Sampling must be conducted using accepted methods and use an appropriate level of care to ensure that the M&V results that rely on the sampling and analysis are sufficiently accurate. This section provides a summary of the concepts, methods and equations to be used.

Although various assumptions regarding the distribution of the sampled data can be made, the large majority of sampling statistical analysis assumes that the data is *normally distributed* about the *mean*.

Statistical validity requires that the samples be randomly selected. Use of a random number generator, such as that found in MS Excel™ is convenient for ensuring the sample is randomly selected

14) Point Estimation – Confidence and Precision

When we use sampling to estimate an average value of an entire population, we are performing an activity know as *point estimation*. A value or 'point' that is estimated based on a sample is not the actual average value but rather, is a value that is "reasonably close" to the actual average value. The question, then, for the M&V practitioner is: “What do we mean when we say ‘reasonably close’?” The question is answered using the following statistical terms:

Confidence: Confidence is fundamentally the same as probability, except that confidence refers to data already obtained, while probability refers to a future value. A confidence of 90% is commonly used in M&V. So, using our 90% example, when we refer to a confidence level, we are saying “I am 90% *confident* that the measured value is within my stated *confidence interval*.”

Confidence Interval (or Precision): Because the value estimated by sampling cannot be expected to be the actual value, it is useful to state an interval in which we have confidence the true value lies. Confidence interval is also often referred to as *precision*. An M&V practitioner may state that they know the value has a *precision* of 10%, which would mean that the “The estimated is within 10% of the true value.”

Confidence and precision, then, are the values referred to when a 90/10 (or 80/20 or any other) criteria is specified.

15) Sample size calculation

HUD recommends that a confidence level of 80% with a precision of 10% be utilized in sampling of all stipulated performance and operational parameters. This confidence level establishes the level of risk acceptable to HUD and the PHA when stipulations parameters are used in calculating energy savings. Exceptions to this policy would include:

1. HUD’s determination that the associated risks are low to the PHA and HUD.
2. HUD’s determination that the M&V costs are excessive as compared to the value of the energy savings.

Required sample sizes are listed below:

a) Formula

$$n = \frac{z^2 \times (Cv)^2}{(P)^2} \qquad n^* = \frac{N \times n}{n + N}$$

n = sample size for infinite population
z = Z-Statistic, 1.645 for 90% confidence level, 1.282 for 80% confidence level
C_v = Coefficient of variation,. 0.5 is typically used for M&V
P = Precision required, typically 10% or 20%
n* = sample size corrected for sample size less than 500

b) Sample Size Table

Sample Size				
Precision (p)	20%	20%	10%	10%
Confidence	80%	90%	80%	90%
Z-Statistic	1.282	1.645	1.282	1.645
n	10.3	16.9	41.1	67.7
Population Size (N) = dwelling units				
10	5	6	8	9
25	7	10	16	18
30	8	11	17	21
40	8	12	20	25
50	9	13	23	29
60	9	13	24	32
70	9	14	26	34
80	9	14	27	37
90	9	14	28	39
100	9	14	29	40
110	9	15	30	42
120	9	15	31	43
130	10	15	31	44
140	10	15	32	46
150	10	15	32	47
160	10	15	33	48
170	10	15	33	48
180	10	15	33	49
190	10	16	34	50
200	10	16	34	51
210	10	16	34	51
220	10	16	35	52
230	10	16	35	52
240	10	16	35	53
250	10	16	35	53

Sample Size				
Precision (p)	20%	20%	10%	10%
Confidence	80%	90%	80%	90%
Z-Statistic	1.282	1.645	1.282	1.645
n	10.3	16.9	41.1	67.7
Population Size (N) = dwelling units				
260	10	16	35	54
270	10	16	36	54
280	10	16	36	54
290	10	16	36	55
300	10	16	36	55
310	10	16	36	56
320	10	16	36	56
330	10	16	37	56
340	10	16	37	56
350	10	16	37	57
360	10	16	37	57
370	10	16	37	57
380	10	16	37	57
390	10	16	37	58
400	10	16	37	58
410	10	16	37	58
420	10	16	37	58
430	10	16	38	58
440	10	16	38	59
450	10	16	38	59
460	10	16	38	59
470	10	16	38	59
480	10	16	38	59
490	10	16	38	59
500	10	16	38	60

Note: Sampled units MUST be randomly generated.

16) Third Party Measurement and Verification Report

HUD may require that a PHA hire an independent third party consultant to validate all stipulated energy savings that are funded by the add-on subsidy incentive. Exceptions to this policy would include:

1. HUD's determination that the associated risks are low to the PHA and HUD.
2. HUD's determination that the M&V costs are excessive as compared to the value of energy savings (e.g. greater than 40%).

If a third party consultant is required, such consultant must comply with the following:

1. The third party M&V to be completed by a licensed professional engineering firm with CEM certification.
2. The third party will generate its own analysis of savings, and not simply review the savings analysis generated by the PHA or the ESCo.
3. The third party reviewer will conduct an independent review of the savings claimed by the PHA and/or the ESCo to confirm that the energy savings are a result of the energy conservation measures and not:
   a. HUD funded measures,
   b. Weather, or
   c. Changes in building unit count.
4. The third party M&V review process is to comply with the HUD M&V guidelines.

5. Conflicts of interest – in a PHA managed contract, a third party consultant who develops the energy audit cannot perform the third party M&V services under the terms of their original contract. Such services may be performed by the third party consultant provided they are procured separately.

The cost of the measurement and verification report and any HUD required audit performed by the PHA or independent third party are an allowable expense under a performance contract.

17) Resident Paid Utilities

Resident Paid Utilities **may** be verified by using the one of the following approaches:

a) Utility Allowance Approach
   i) Within an energy performance contract there are three separate utility allowances. They include:
      (1) Existing utility allowances. These are the utility allowance in existence prior to the PHA / ESCo performing any review.
      (2) PRE or Baseline utility allowances. These are the utility allowances developed by the PHA / ESCo before any savings measures are begun. These utility allowances are based upon an engineering analysis of the existing utility allowance. Federal regulations 24 CFR 990.185 (2)(i) states: "(i) The PHA reviews and updates all utility allowances to ascertain that residents are receiving the proper allowances before energy savings measures are begun;"
      (3) POST utility allowance – The post utility allowances are calculated during the EPC development process and reflect what the utility allowances will be after the energy conservation measures have been installed.
   ii) The PRE utility allowance must be an engineering based utility allowance defining values for all performance and usage parameters.
   iii) The PRE utility allowances must be statistically validated by measuring actual consumption or meter readings at sampled dwelling units.
   iv) The POST utility allowances will utilize the same usage parameters as the PRE utility allowances, updating the performance parameters for the installed energy conservation measures.
b) M&V Approach
   i) Energy savings for each energy conservation measure will be determined based upon the M&V procedures contained in this document.

END