# DETAILED GUIDELINES FOR FEMP M&V OPTION A

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# CONTENTS

# Glossary of Abbreviations and Acronyms

| Acronym | Definition |
|---|---|
| ASHRAE | American Society of Heating, Refrigeration, and Air-Conditioning Engineers |
| CDD | Cooling-degree days |
| DOE | U.S. Department of Energy |
| DSM | Demand-side management incentive programs sponsored by utility companies |
| ECM | Energy-conservation measure |
| EMCS | Energy management and control system |
| EPRI | Electric Power Research Institute |
| ESCO | Energy service company |
| ESPC | Energy savings performance contract |
| FEMP | Federal Energy Management Program |
| IPLV | Integrated part-load value |
| M&V | Measurement and verification |
| MVP | *International Performance Measurement and Verification Protocol*, 2001 |
| NREL | National Renewable Energy Laboratory |
| O&M | Operations and maintenance |
| TMY | Typical Meteorological Year weather data—available from the National Oceanographic and Atmospheric Administration |
| VSD | Variable-speed drive, also known as variable-frequency drive, adjustable speed drive |
| W | Watts |

# 1. INTRODUCTION

This document is an extension of the guidance issued by the U.S. Department of Energy's Federal Energy Management Program on measurement and verification of energy and cost savings associated with energy savings performance contracts — *M&V Guidelines: Measurement and Verification for Federal Energy Projects* (Version 2.2). The M&V Guidelines identify four general approaches to measurement and verification of savings: Options A, B, C, & D. This document focuses on the proper use of Option A methods.

The target audience for this document are measurement & verification practitioners, project facilitators, and agency technical representatives such as energy managers and facility operators. This document assumes that the reader is familiar with performance contracting in general and SuperESPC in particular and is comfortable with technical, engineering, and mathematical discussions.

## *1.1 WHAT IS 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 data collection, engineering calculations, and stipulated factors. Post-installation energy use is not measured throughout the term of the contract. Post-installation and baseline energy use is estimated using an engineering or statistical analysis of information that does not involve long-term measurements. *Option A forbids the direct stipulation of savings.*

With Option A, savings are determined by measuring the capacity, efficiency, or operation of a system before and after a retrofit and by multiplying the difference by a stipulated factor. While stipulated values are usually easier and less expensive to derive, such stipulations are typically the least accurate method and contribute the greatest uncertainty to the savings estimate. This level of verification is suitable where the primary concern is equipment performance and where both parties agree to a payment stream that is not subject to fluctuation due to changes in the operation (usage) of the equipment.

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 chiller retrofit. If greater accuracy is required, Options B, C, or D may be more appropriate.

## *1.2 PURPOSE*

This document provides detailed guidance for using the Option A measurement & verification methods described in the FEMP *M&V Guidelines.*. The Option A guidelines have two primary uses:

(1) as a reference for specifying Option-A–compliant M&V methods and procedures in delivery orders, requests for proposals, and performance contracts, and

(2) as a resource for those developing or reviewing Option A M&V plans for federal ESPCs.

The principal purpose of these guidelines is to provide the information that federal agencies, energy service companies, and others who need to ensure that if they use the stipulations allowed by Option A methods, they use them appropriately and achieve the intended effect.

Using stipulated values for determining savings can be a practical, cost-effective way to minimize M&V costs. 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 can shift some risk to the agency, and the agency should thoroughly understand the risks before accepting them. This document discusses how Option A methods and stipulations can be used to apportion risks and responsibilities and how to make the M&V method work with, not against, the savings guarantee. Using these guidelines will give federal agencies and others the information needed to apply Option A M&V methods with confidence.

### 1.3 SCOPE

These guidelines describe detailed methods of applying stipulations to the energy-conservation measures (ECMs) specifically covered in the FEMP *M&V Guidelines*: lighting, motors, variable-speed drives, and chillers. The guidelines also discuss using stipulations in projects involving boilers, energy management and control systems (EMCS), water conservation, new construction, operations and maintenance (O&M), and renewable energy. The prescribed procedures are impartial, reliable, repeatable, and can be applied with consistency to similar projects in any geographic region.

### 1.4 RELATIONSHIP TO MVP

The Option A guidelines also bridge most of the differences between the FEMP *M&V Guidelines* and the latest revision of the *International Performance Measurement & Verification Protocol* (MVP, 2001), as discussed in section 2.1.4. MVP was written by and for technical, procurement, and financial personnel in government and the private sector to establish a framework for verifying performance in financed energy projects. The FEMP *M&V Guidelines* are an application of MVP to federal energy projects and are intended to be fully consistent with MVP. However, some variances remain between FEMP and MVP. These differences are clearly noted in the document and in Table 5-1.

## 2. THE DEFINITION OF STIPULATION IN OPTION A

Energy savings (along with operations and maintenance and water savings) are determined by comparing the energy use before and after the installation of energy conservation measures in the associated facility. In general,

$$\textit{Savings} = (\textit{Baseline energy use})_{adjusted} - (\textit{Post-installation energy use}).$$

Baseline and post-installation energy use depend on various system and external factors such as energy demand, operating hours, weather conditions, motor loading, and occupancy. These factors may be highly variable, difficult to determine, and their relationships to energy use may be complex. If so, extensive measurements and detailed analyses would be required to accurately characterize the relationships between these factors and energy use, which is time- and equipment-intensive and relatively expensive.

In many cases, however, the factors determining energy use are less variable or well known, and their relationships to energy use are straightforward. Under these circumstances, Option A methods may be used. Option A methods allow certain parameters to be stipulated instead of measured if they can be reasonably estimated, are documented, and their contribution to the overall uncertainty associated with achieving guaranteed savings is small.

## 2.1 THE DIFFERENCE BETWEEN MEASUREMENT AND STIPULATION

### 2.1.1 Stipulation

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 ESPC M&V plan is an agreement between the ESCO and agency to accept a defined value or functional form of a specific factor to be used in determining the baseline and/or post-installation energy consumption, which will be used to calculate the guaranteed savings. If related requirements are met (e.g., satisfactory commissioning results were submitted, annual verification of equipment performance is performed, and that maintenance is being done), the guarantee is considered to be met.

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, or
- 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, verifying equipment performance (technically, the *potential to perform*) is still required. *Note that direct stipulation of energy savings is not allowed.*

### 2.1.2 Measurement

*Measured* factors are quantified by metering or monitoring of individual components, systems, or buildings. Measurements can be taken continuously, for hours, days, or weeks, or for moments to obtain data "snapshots." Data from these measurements are used to calculate savings using engineering calculations or models, regression or other analysis algorithms, or computer models.

### 2.1.3 Measurement and Stipulation as Technical Terms

For Option A methods, 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 the ESCO and the agency, they will be held constant during the contract term.

### 2.1.4 New Definitions in MVP 2000

The 2001 version of MVP revised the definitions of Option A and stipulation, which makes them different from those in the FEMP *M&V Guidelines*. Under MVP 2001, Option A is now called "partially measured retrofit isolation," and compliance with MVP requires measuring at least one parameter. FEMP guidelines still allow verification without measurement in some cases. These Guidelines address this inconsistency by encouraging the use of measurements wherever practical and by showing which Option A methods no longer comply with MVP.

Also MVP 2001 defines a stipulated factor to be estimated or assumed but not measured, while FEMP's guidelines include measurements as a possible source of information for stipulations. Under the current FEMP guidelines, *stipulate* means that the parameter will be held constant during the contract term and that its value is "based on reliable, documentable, and traceable sources of information." These Option A guidelines have adopted the MVP definition of stipulation, and its use in this document implies that no measurement is made.

A subtle difference between MVP and the FEMP guidelines is that MVP attempts to minimize uncertainty while FEMP attempts to allocate risk to the responsible parties. For example, MVP recommends measuring lighting operating hours instead of fixture demand because there is usually a greater uncertainty in the operating hours. FEMP's guidelines, on the other hand, encourage measuring fixture demand because that is the aspect over which the ESCO has some control. Operating hours is a usage factor that may vary based on agency behavior—a factor beyond the ESCO's control and therefore not appropriately the ESCO's responsibility.

## 3. Deciding Whether to Use Stipulations

Properly used, stipulations can reduce M&V costs and simplify procedures. Improperly used, they can give M&V results an undeserved aura of authority. Deciding whether parameters should be stipulated requires understanding how they will affect savings, judging their affect on reliability and uncertainty of results, and balancing agency desires with the costs, risks, and goals of the project.

Evaluation of a few key aspects of the ESPC project should drive decisions about whether to use stipulations and how to use them effectively in an M&V plan:

- the magnitude of the measure's cost savings,
- availability of reliable information,
- the project's likelihood of success,
- uncertainty of the stipulated parameter and its contribution to overall project uncertainty,
- the cost of measurement, and
- responsibilities of the ESCO and agency.

The discussions below of three concepts in the M&V context—uncertainty, risk and responsibility, and cost—provide background for the guidelines given in the material that follows.

### 3.1 CONSIDERING UNCERTAINTY

Overall savings uncertainty, and how much individual parameters contribute to overall uncertainty, should be carefully considered in deciding whether to use stipulations. Savings uncertainty can be assessed by identifying the factors that affect savings and estimating the potential influence of each. Factors having the greatest influence should be measured if at all practical. (See the appendix for an example of calculating uncertainty in savings estimates for a representative lighting project.)

Figure 3-1 illustrates the relationships between savings uncertainty, magnitude of savings, and whether stipulation is recommended. Several "rules of thumb" that flow from these relationships are listed below and keyed to the figure:

(1) The most certain, predictable parameters can be estimated and stipulated without significantly increasing uncertainty.

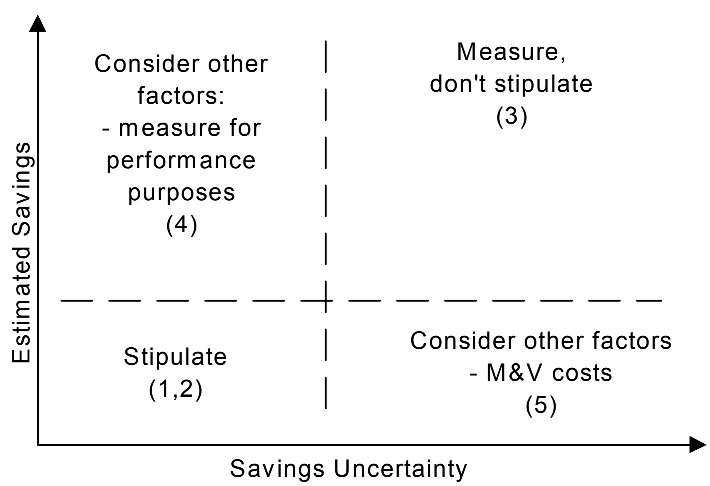
(2) Stipulating parameters that represent a small degree of uncertainty and a small part of overall savings will not increase uncertainty significantly.

(3) Parameters that represent a higher percentage of project savings and uncertainty should be measured.

(4) If estimated savings are high but uncertainty is low, measurement may not be necessary for M&V purposes. However, the budget will support measurements which could be used for monitoring equipment performance and diagnosis as well as for M&V.

(5) If estimated savings are small and uncertainty is high, stipulation would only shift risk to the agency, and consideration of whether the ECM is worthwhile might be warranted.

Figure 3-1: Measure vs. Stipulate



Parameters that can vary over time because of weather, performance degradation, occupant behavior, or other factors will always be uncertain. Whether these values should be measured or stipulated depends on who will assume the uncertainty risk.

## 3.2 HOW STIPULATIONS APPORTION RISKS AND RESPONSIBILITIES

One of the 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. M&V plans should include a list of potential risks and identify the party responsible for managing those risks. The Responsibility Matrix in FEMP's *M&V Guidelines* (in Section I, Chapter 2) lists risks and responsibilities that agencies and ESCOs should consider when developing M&V plans and is a convenient tool for this task.

Appropriately used, stipulations can be used to precisely craft the guarantee and apportion risks and responsibilities. "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 stipulations are often used to match control and responsibility. In addition to financial considerations, risks in energy projects can be categorized as relating to either equipment performance or operational factors (usage).

### 3.2.1 M&V Without Stipulations Leaves Risk with the ESCO

If no stipulated values are used and savings are verified based entirely on measurements, then all risk resides with the ESCO, who must show that the guaranteed savings are realized and compensate the agency for any shortfall, regardless of contributing factors.

### 3.2.2 Stipulations Shift Risk to the Agency

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. The agency assumes the risk for the parameters that are stipulated. In the event that the stipulated values overstate the savings or reductions in use decrease the savings, the agency must still pay the ESCO for the agreed-upon savings. If the actual savings are greater than expected, the agency retains all of the savings.

### 3.2.3 Operational Risk—Typically Assumed by the Agency

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 financial 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. Then the ESCO is not responsible for unrealized saving resulting from decreasing usage.

The potential consequences to the agency of stipulating usage factors are small if the stipulated value can be estimated to a reasonable degree of certainty and represents an appropriately small proportion of overall project uncertainty. Risk is minimized through diligent estimation of the stipulated value.

Long-term risk is mitigated by the fact that a variance from stipulated usage is offset by the correlated variance in utility bills. For example, if lighting operating hours fall below historic levels, savings will be reduced, but so will actual utility bills. If lighting hours increase, utility bills will increase but so will savings. In the second case, the utility bills will *increase less than they would have* if no lighting improvements were made.

#### 3.2.4 Equipment-Performance Risk—Typically Assumed by the ESCO

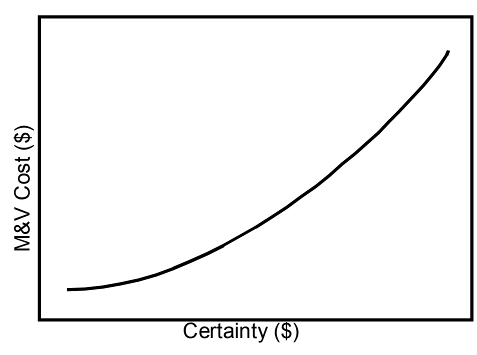
Performance risk is the uncertainty associated with characterizing a specified level of equipment performance. The ESCO is ultimately responsible for selection, application, design, installation, and performance of the equipment and typically assumes responsibility for achieving savings related to equipment performance. To validate performance, the ESCO must (at least) demonstrate that the equipment is operating as intended and has the potential to deliver the guaranteed savings. This usually requires measuring performance, but not always. The ESCO also must achieve specified standards of service (temperature, humidity and lighting levels, etc.).

If performance parameters are stipulated rather than measured, then the agency is assuming the risk of unrealized savings. For example, if equipment efficiencies are stipulated, the ESCO has no motivation to ensure that optimal efficiencies are maintained, because nominal savings will be calculated using the stipulated efficiency value. Actual savings, however, will be unknown.

### *3.3 M&V Cost*

M&V cost is an important factor in deciding whether to use stipulations. M&V methods generally yield greater accuracy and certainty in proportion to their cost. Figure 3-2 illustrates how more rigorous—and thus more costly—M&V reduces savings uncertainty. At some point the incremental reductions in savings uncertainty are no longer justified by the increased M&V costs.

Figure 3-2: Certainty and M&V Cost




Agencies generally use the least expensive M&V option that provides sufficient certainty that savings guarantees are met. It makes good sense to perform just the level of M&V needed because M&V costs reduce the amount of savings available to finance a project. Option A methods are generally less expensive than those that use more measurements or complex analysis.

Agencies and ESCOs planning for M&V activities should investigate a range of strategies for containing M&V costs, such as the following:

• Include an energy management & control system (EMCS) comprising sensors and other measurement equipment as an ECM in the project and use it for data collection.

• Use remote data downloading instead of more labor-intensive data collection and analysis methods.

• Use simple but robust analysis algorithms.

• Consider using Option C (utility bill analysis). Option C is an appropriate and cost-effective method if facility operation is stable and savings are expected to exceed 20% of total energy consumption. Regression analysis can be used to account for weather and other factors to adjust the baseline and determine savings. However, Option C cannot be used to verify component-level performance if more than one measure is installed.

# 4. USING STIPULATIONS

## 4.1 PARAMETERS COMMONLY STIPULATED

Parameters commonly stipulated include lighting operating hours, lighting fixture power, and constant-volume fan powers and schedules. Once equipment performance and schedules have been characterized, these parameters may be stipulated for the baseline case (and possibly for the post-retrofit case as well). More complex parameters that are sometimes stipulated include chiller performance curves and equipment load frequency distributions (e.g., hours per damper position, hours per motor speed, hours per chiller load). Measurements are often required to confirm performance curves or load frequencies (usually during the baseline audit or commissioning of the newly installed equipment). If these parameters can be reliably and safely estimated, they may be stipulated instead of measured.

## 4.2 CONDITIONS INDICATING THAT STIPULATION IS OR IS NOT APPROPRIATE

### 4.2.1 Positive Indicators

Using stipulated values in savings estimates is usually appropriate if some or all of the following apply:

- The ECM
    - — has a high probability of delivering expected savings.
    - — contributes a small percentage to overall project savings.
    - — contributes a small percentage to overall project uncertainty.
- The agency
    - — is willing to accept some uncertainty.
    - — has experience with similar ECMs.

- The cost of measurement is not justified by the value of reduced uncertainty.
- Measurement or monitoring serves no other purpose (such as performance monitoring or diagnostics).
- The ESCO has no control over the factor at issue (such as operating hours).

If there are multiple measures in a project, stipulations may be used with measures that don't represent a significant portion of the overall savings or don't significantly contribute to the overall uncertainty. Doing so can reduce M&V costs without increasing uncertainty. Parameters that have only a minor effect on the savings estimates may be stipulated, especially if they are difficult or expensive to measure. Values stipulated for all such parameters still need to be documented.

#### 4.2.2 Negative Indicators

Using stipulated values may be inappropriate if one or more of the following conditions apply:

- The agency is not willing to assume risk.
- Parameters are not known with reasonable certainty or are highly dependent on external factors (e.g., variable-speed drives on fans, lighting occupancy sensors).
- The measure has an uncertain probability of success; for example, it has significant potential for technical problems.
- The cost of measurement is more than justified by the increased accuracy and value of performance feedback.

### *4.3 Sources of Information*

The stipulated parameters will affect the reported savings over the entire contract term. All stipulations 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 EMCS records are the preferred information source, such information may not be available or be costly to obtain. Sources of information on which stipulations may be based include the following (in order of preference):

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

Stipulated 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 information
- Guesses at operating parameters
- Equations that do not make mathematical sense or are derived from questionable data

There are always exceptions to any rule. It is not the intent of these guidelines to inhibit a project where information is not available from sources specifically mentioned here.

### 4.4 REQUIRED M&V ACTIVITIES

Using stipulations reduces—but does not eliminate—the need for other M&V activities. All SuperESPCs require defined energy-usage baselines, savings estimates, guaranteed savings relative to baselines, and procedures to verify performance and savings. Measurement & verification activities need to conform to the requirements of the Delivery Order contract and to the FEMP *M&V Guidelines*. Required M&V activities include the following:

• M&V plans must show how performance of each ECM will be demonstrated, including calculations, assumptions, and sources of stipulated values. The ESCO's M&V plan must outline and schedule procedures to be performed during the contract term. The plan must specify periodic activities that will verify the ECMs' continuing potential to deliver guaranteed savings and that performance standards are achieved.

Where stipulations are used,

(1) the source of information and how it will be applied must be shown;
(2) their influence on savings uncertainty should be discussed; and
(3) their use (instead of measurements) should be justified.

• Commissioning. After installation is completed, the ESCO must demonstrate the potential of the ECMs to perform as specified. The Post-Installation Report should include M&V data resulting from commissioning as well as estimated first-year savings. The agency should not accept the project before it reviews this report and is assured that the ECMs were installed properly, are operating as expected, and show the potential to deliver guaranteed savings.

• Annual M&V reports are required in federal ESPC projects. ESCOs are required to submit annual reports that document savings in accordance with agreed-to procedures, show how they compare to guaranteed savings, "true-up" savings relative to the guaranteed amounts if necessary, and document other required activities.

# 5. MEASURE-SPECIFIC GUIDELINES FOR USING STIPULATIONS IN FEMP OPTION A

Guidelines for using Option A for the ECMs included in the FEMP *M&V Guidelines*, plus some additional technologies are presented in this section. Table 5-1 lists which FEMP methods are MVP-compliant and which are not.

Table 5-1: IPMVP compliance of specific FEMP M&V approaches.

| Measure Type | FEMP Method Number | MVP-compliant |
|---|---|---|
| Lighting Efficiency | LE-A-01 | Yes* |
| | LE-A-02 | Yes |
| Lighting Controls | LC-A-01 | No |
| | LC-A-02 | Yes |
| Constant-Load Motor Efficiency | CLM-A-01 | Yes |
| Variable-Speed-Drive Retrofit | VSD-A-01 | Yes |
| Chiller Replacement | CH-A-01 | No |
| | CH-A-02 | Yes |
| Boiler Replacement or Upgrade | – | Yes** |
| Energy Management & Control System | – | Yes*** |
| Water Conservation | WCM-A-01 | No |
| | WCM-A-02 | Yes |
| New Construction | NC-A-01 | Yes*** |
| Operations & Maintenance | – | N/A |
| On-Site Generation | – | N/A |
| Renewable Energy Systems | – | Yes*** |

* If fixture powers are taken from a table based on measurements.
** If boiler efficiency is measured.
*** If equipment performance is measured.

## 5.1 LIGHTING EFFICIENCY

For the Option A methods for lighting efficiency, the operating hours may be stipulated because the agency will be assuming the responsibility for fixture run-time. Method LE-A-01 does not require metering of fixtures; method LE-A-02 requires spot or short-term power measurements of a representative sample of baseline and post-installation fixtures or fixture circuits to establish demand. Method LE-A-01 can be considered MVP-compliant if fixture powers are taken from a measurement-based source such as manufacturer's test data or tables such as those developed by the Electric Power Research Institute (EPRI) or those used in utility DSM programs. Method LE-A-02 is MVP-compliant because fixture power is directly measured.

Of the two parameters that affect lighting savings — operating hours and fixture power — operating hours are often the more uncertain and the most likely to change over time. Despite this, hours may be stipulated instead of measured because the agency is assuming the risk of change. The ESCO is guaranteeing the savings based on the performance (expressed as demand reduction) of the lighting fixtures, so the FEMP guidelines encourage measuring that parameter.

Despite claims that lighting operating hours are known with reasonable certainty, experience has shown that there is often considerable uncertainty even in “certain” operating hours. Nighttime cleaning crews, inflexible or failed controls, and random human behavior contribute significant uncertainty to assumed operating hours. If stipulations are to be used, operating hours should be well characterized and documented. Short of actual measurements, the best source of data on operating hours is the building and occupant schedule corroborated by daytime and nighttime observations. Operating hours so derived should consider the effect of evening cleaning crews, after-hours and weekend operations, controls that require illuminating an entire floor when only one person is present, and limited use due to daylighting. If uncertainty still exists after considering these factors, short-term monitoring may be preferable to stipulating the operating hours.

Fixture powers can be measured or can be taken from a “standard” table. While it is expected that actual fixture powers will agree closely with standard lighting tables, this may not always the case. There will be differences due to fixture type (thermal properties), manufacturer’s ratings, and actual vs. assumed equipment installed (e.g. 40-W vs. 34-W fluorescent lamps, or standard vs. “energy-saving” magnetic ballasts). Minimizing uncertainty requires taking sampled measurements instead of using standard tables.

Reducing the lighting load in an interior space will reduce the amount of air conditioning required and lead to additional energy savings. These savings may be offset by the increase in required heating energy. Interactive cooling savings and heating penalties can be estimated through engineering calculations or computer models. One simple method of estimating lighting interactive factors is outlined by Rundquist.[1]

Additional savings are usually achieved by lowering the facility’s total electric demand, which is billed separately from energy usage. Utilities calculate demand charge by measuring the building or facility peak demand during the month. This peak demand usually occurs in the late afternoon when cooling loads are highest. The amount of demand reduction achieved by a lighting project will depend on how many of the lights are operating when the building peak demand occurs. It is unlikely that all lighting fixtures will be operating when the peak demand is set, so summing the demand reduction from all affected fixtures will overstate the demand reduction seen in the utility bill. The fraction of lights operating when the peak demand is set is known as the *diversity factor*, which can range from 0% (outside lights that operate only at night) to 100% (continuously operating lights). It is difficult to accurately determine diversity factors without taking time-of-use measurements. If diversity factors (by usage group) are to be stipulated, they can be estimated from walk-through observations by noting the percentage of fixtures operating during the time the building peak demand is most likely to be set.

### 5.1.1 Recommended Practice for Lighting Efficiency

For projects where savings are expected to be $10,000 or less, method LE-A-01 may be most appropriate. Fixture powers for common lamp & ballasts combinations can come from a standard table such as that used by the local utility’s DSM or standard performance contract incentive

[1] Rundquist, “Calculating Lighting and HVAC Interactions," *ASHRAE Journal* 35, no. 11 (1993).

programs. An accurate baseline inventory is essential to this method's success. (One should pay close attention to the mixture of F34 and F40 lamps and ballast type in existing fixtures, i.e., standard magnetic vs. "energy-saving" magnetic ballasts.) The source of the table should be documented and the table itself included in the M&V plan. Operating hours for each usage group can be based on building schedules and observed behavior. Attention should be paid to after-hours operation, cleaning-crew schedules, and daylighting effects. Diversity factors can be estimated from afternoon walk-through observations.

For projects where savings are expected to be between $10,000 and $100,000, choice of method LE-A-01 or LE-A-02 should be based on perceived project risks and the agency's risk tolerance. Operating hours should be characterized more rigorously than those for smaller projects. Although not required, using light loggers on a sample of spaces to determine operating hours and diversity factors is encouraged.

For projects where savings exceed $100,000, method LE-A-02 is preferred. Sampled measurements of three to six fixtures of the most common types should be made[2]; fixture powers for uncommon types can come from a standard lighting table. Using lighting loggers to monitor operating hours of the major usage groups is strongly encouraged.

Fixture monitoring can be performed as a one-time measurement using time-of-use loggers, either pre-retrofit or post-retrofit. A monitoring period of three weeks is recommended with one week being the minimum acceptable period. Logging should be performed during the Detailed Energy Survey to establish the baseline operating hours.

While the FEMP *M&V Guidelines* do not specify uncertainty and confidence intervals for measurements, the use of 20% uncertainty at an 80% confidence interval is reasonable for operating hour logging. This will require a one-time measurement of up to 11 spaces per usage group.

### *5.2 LIGHTING CONTROLS*

Option A methods for lighting controls measures —LC-A-01 and LC-A-02— are similar to those for lighting efficiency measures. Both methods may use stipulated pre- and post-installation operating hours. Some lighting controls measures—such as time-clocks or other controls which proscribe lighting schedules—support the use of stipulations. Conversely, occupancy sensors are highly dependent on human behavior and installed location and therefore, stipulated pre-and post-retrofit operating hours are discouraged for all but the smallest projects.

Method LC-A-01 does not require metering of fixtures; method LC-A-02 requires spot or short-term wattage measurements of a representative sample of baseline and post-installation fixtures or fixture circuits to establish demand. Method LC-A-01 parallels LE-A-01 and can be considered MVP-compliant if lighting tables based on measurements are used. It should be understood that there will be considerable uncertainty in the operating hours due to stipulation. Method LC-A-02 is MVP-compliant because one parameter (fixture power) is measured.

[2] This is less than the sample sizes suggested by FEMP Guidelines Table D-2 because the typical $C_v$ of fixture power measurements is on the order of 0.1, significantly less than the 0.5 on which table D-2 is based. See the Appendix for additional discussion and justification of this recommendation.

However, MVP encourages the least certain parameter to be measured, which in this case would be the operating hours.

Occupancy sensors provide a special challenge when attempting to estimate the reduction in operating hours they provide. Although recognized agencies such as the U.S. Environmental Protection Agency and EPRI have published "typical" savings values from occupancy sensors, they should be used for planning and estimating purposes, not as a source for stipulated values.

Short-term monitoring provides the most reliable site-specific information and is the preferred method for large projects. Ideally, occupancy loggers are used in a sample of spaces to determine the operating hours. If occupancy loggers are not available, lighting loggers could be used in a sample of spaces that have had lighting controls installed. Because of large variations in expected results, short-term monitoring should last a minimum of three weeks during non-holiday periods.

Regardless of whether post-retrofit operating hours are measured or stipulated, long-term performance should still be verified by inspecting to ensure that the lighting controls are still functional. Occupancy sensors can be overridden or have their time-out values set so high as to make them ineffective. Annual inspections should be performed to show that sensors turn off lights in a reasonable amount of time (10–30 minutes).

The procedure for estimating interactive cooling savings and heating penalties for lighting controls measures is identical to that for lighting efficiency measures.

### 5.2.1 Recommended Practice for Lighting Controls

Stipulated operating hours are generally not recommended for occupancy sensors due to their high uncertainty. Recommended practices for schedule-based lighting controls follow those for efficiency upgrades LE-A-01 and LE-A-02. Emphasis should be placed on characterizing the reduction in operating hours. If light logging is used, both pre-retrofit and post-retrofit monitoring should be performed. Because of the large variability in post-retrofit operating hours, it is recommended that a longer monitoring period of three weeks be used. Shorter periods may yield inconclusive results.

The sample size table in Appendix D of the FEMP guidelines for determining sample sizes is based on an assumed $C_v$ (coefficient of variation) of 0.5. The $C_v$ for operating hours for fixtures with motion sensors is often greater than 0.5, and it is suggested that samples sizes be based on assumed $C_v$ of 0.75. This will increase the maximum sample size per space from 11 to 25 to achieve 20% uncertainty at 80% confidence.

## *5.3 CONSTANT-LOAD MOTOR EFFICIENCY*

In many respects, constant-load motor efficiency projects are similar to lighting efficiency projects in that savings are primarily due to demand reduction. Energy savings are a function of reductions in electrical demand, changes to motor load, and operating hours. The Option A method for motor efficiency measures, CLM-A-01 assumes that the motors operate at a constant load with a definable operating schedule that can be stipulated. Both of these assumptions should be verified to the greatest extent practical. CLM-A-01 is MVP-compliant.

Metering is required on at least a sample of motors to determine the average power draw for baseline and new motors. Demand reduction is the difference between baseline and the post-retrofit demand. Meters used to measure motor demand should be capable of measuring true kW and power factor, not just voltage and current.

For fan and pump applications, it is also useful to measure RPM with a stroboscopic tachometer. This will help identify changes in operation due to differences in motor slip characteristics following retrofit. If the speed of a fan or pump changes, the power draw will also change and may reduce or eliminate any savings. Having a measured value for baseline RPM allows changing the drive sheave to restore the original drive speed, thereby ensuring that savings will be achieved.

*Load factor* is calculated from measured power and nameplate information and shows the amount of power the motor is delivering relative to its rated power. While assumed load factors can be used to initially estimate *potential* savings, they can not be used to verify savings. Load factors are not intrinsic to the motor and may not be consistent within applications or across motor sizes (e.g., not all fan motors will operate at the same load factor).

Good sources of estimated hours that can be stipulated include operation logs, EMCS schedules, or time-clock controls. If these are not available, it may be necessary to perform some run-time monitoring on a sample of motors.

If the baseline and post-retrofit operating hours will be different, then both sets of hours need to be documented to a similar degree. Schedules from an EMCS or time-clock can be used to document operating hours for each controlled motor. If these are not available, it may be necessary to perform some run-time monitoring on a sample of motors.

### 5.3.1 Recommended Practice for Constant-Load Motor Efficiency

For all motor replacement projects , one-time measurements of pre- and post-retrofit kW on a sample of motors is required. Rotation speed of the motor or the driven equipment should be taken where practical. Motors should be divided into usage groups by size, RPM, and application (10 HP 3600 RPM fans, 5 HP 1800 RPM pumps, etc.), and samples from each group selected at random. Sample sizes should be developed in a manner analogous to that described in lighting efficiency method LE-A-02 as outlined in Appendix D of the FEMP M&V Guidelines version 2.2.

Pre-retrofit measurements should be made during the Detailed Energy Survey; post-installation measurements can be made during construction or commissioning. Operating hours can be stipulated as discussed previously.

For projects where savings are expected to be greater than $10,000, the previous recommendations should be followed along with short-term data logging (on/off or current) to establish operating hours. Where operating hours are not easily established (e.g., not continuous, time-clock, or EMCS controlled), short-term data logging (on/off or current) should be used to establish operating hours.

## *5.4 VARIABLE-SPEED DRIVES*

Variable-speed-drive (VSD) projects involve the addition of VSD controllers to modulate motor speed in response to some changing parameter. These projects reduce energy use but do not necessarily reduce utility demand charges. Often, VSD retrofits also include installation of high-efficiency motors. Typical VSD applications include HVAC fans and chiller circulating pumps.

The prescribed Option A method, VSD-A-01, is only appropriate for VSD projects in which, for the baseline and post-installation motors, the following apply:

- Electrical demand varies as a function of operating scenario. For example, damper or three-way valve position for the baseline case and motor speed for post-installation case; the electrical demand for each operating scenario can be defined with spot measurements of motor power draw.
- Operating hours as a function of operating scenario can be stipulated.

This method assumes that the agency and the ESCO are confident that the affected motors operate with definable operating schedules and scenarios that can be stipulated. Option VSD-A-01 is MVP-compliant.

Spot metering is required on at least a sample of the existing motors to determine baseline motor power draw under different operating conditions. Constant-load motors may require only one measurement if the power draw does not vary with time or operating conditions. Operating conditions such as control valve or damper positions (for baseline) or motor speeds (for VSDs) will require measurements over a range of positions or speeds. Ideally, two characteristic performance curves would be developed that would be used to estimate savings.

Post-installation spot metering is required on at least a sample of motors with VSDs. Post-installation spot metering is done while the motors' applicable systems are modulated over their normal operating range (or range of motor speeds). Demand and energy savings are based on the following:

- Baseline motor kW as a function of different operating conditions
- Post-installation motor kW as a function of different operating conditions
- Stipulated hours per year for each operating condition

Sources of stipulated hours can be any of the following (in order of preference):

- Operator logs or documented schedules from energy management systems
- Results from building simulation models
- Relationships based on TMY weather data (if applicable)

Operating hours can be estimated for each individual motor or for groups of motors with similar applications and schedules. Examples of such motor groupings are supply fan motors, exhaust fan motors, and boiler circulating pump motors. Each group type should have similar use patterns and comparable average operating hours. If a reliable or applicable source of operating hours is not available, short-term metering or EMCS monitoring is recommended.

#### 5.4.1 Recommended Practice for Variable-Speed Drives

The use of Option A methods for VSD applications is limited to systems whose operating parameters are well known, as discussed above. Method VSD-A-01 requires measuring operating power under different load scenarios on a sample of motors or systems. Only usage characteristics can be stipulated. Measurements need to be performed both pre- and post-retrofit.

Sample sizes should be developed in a manner analogous to that described in lighting efficiency method LE-A-02.

Measurements over a range of conditions can be taken either by running equipment through its load range or using data loggers to measure current and other relevant parameters. Regression models, engineering equations, and/or bin analysis can then be used to adjust performance to stipulated usage conditions.

### *5.5 Chiller Replacement or Improvement*

For Option A method CH-A-01, both chiller efficiency (e.g., kW per ton) and the chiller loads (e.g., ton-hours per year) are stipulated. For Option A method CH-A-02, the chiller efficiency is measured and the chiller loads are stipulated. These methods are appropriate for projects in which the baseline and post-installation chiller efficiency and/or the chiller loads are well-defined. Because the ESCO has control over equipment selection, installation, and (in some cases) maintenance, there is justification for greater monitoring of chiller efficiency versus monitoring chiller load. Method CH-A-01 is not MVP-compliant; CH-A-02 is.

While there is a significant advantage to measuring chiller performance to reduce uncertainty, chiller performance measurements are neither trivial nor cheap. Chiller loads must be known, which requires water-side measurements using a quality flow meter and precision temperature sensors. Coincident three-phase power measurements at high current or high voltage are also required. To capture a full range of load conditions may require monitoring for several days to several weeks. While option CH-A-02 is the preferred approach for many projects, option CH-A-01 is available to retain M&V flexibility even though it is not MVP-compliant.

Sources of stipulated baseline and post-installation chiller ratings [such as kW per ton, Coefficient of Performance (COP), and Integrated Part-Load Values (IPLV)] can be manufacturer's or other documented data sources. Chiller efficiencies can be described as IPLV ratings, or chiller curves over the load range can be used. Since chiller performance usually degrades slightly over time, using manufacturer's original specifications for old chillers should provide a conservative baseline performance value. Performance degradation factors should be closely evaluated, and may not be appropriate in all cases. If manufacturer's data are used for a new chiller, at least a single performance measurement should be taken following installation to verify that the chiller is operating on its rated curve. Modern chillers have control panels that provide some or all of the information required to determine performance, although the accuracy may be less than desirable. Standard chiller performance models developed by ASHRAE and used in DOE-2 can be used to adjust measured performance to standard or any other conditions for comparison to rated performance data.

Sources of stipulated cooling load data can be based on the following:

- Calculations of cooling load based on recognized procedures such as ASHRAE's CLTD/CFM[3] methods, bin analysis with applicable weather data, or calibrated computer simulation programs such as DOE-2, BLAST, EnergyPlus, Trace 700, or HAP.

[3] ASHRAE Handbook of Fundamentals describes the Cooling Load Temperature Difference (CLTD) and Cooling Function Method (CFM) for determining air conditioning loads.

- Chiller logs and concurrent TMY weather data

Building simulation results should be calibrated to existing conditions and energy use if at all possible. Chiller logs can be used to establish cooling loads, but log entries are often at infrequent intervals, contain incomplete data, or are unreliable. Using chiller logs will also require correlating loads with reliable weather data for the same period.

If metering data is available (EMCS or other), it is preferable to develop regression models that correlate cooling load to weather data and then adjust cooling loads to represent typical cooling loads. Cooling load data should cover sufficient weather and load ranges to allow regression model development so that load can be extrapolated to a full year.

Baseline and post-installation cooling loads may be different as a result of other measures such as lighting retrofits, VSD additions, or controls upgrades. These load changes should be considered when estimating savings. To avoid double-counting the savings, chiller savings should be based on the post-retrofit internal loads.

Performance of chiller plants can vary significantly from design specifications and can degrade over time. Therefore, ongoing measurement of chiller plant performance should be considered even if future performance is not guaranteed by (or the responsibility of) the ESCO. Monitoring of chiller plant performance has value to the owner as it can be used to optimize the system, for diagnostics, and for scheduling maintenance. If an EMCS is present it can be expanded to monitor the relevant performance parameters. However, this will require a water mass-flow meter and precision temperature sensors, all of which will require periodic calibration.

### 5.5.1 Recommended Practice for Chiller Replacement or Improvement

For projects where savings are expected to be less than $10,000, method CH-A-01 may be appropriate simply because of the potential cost of performance monitoring may not be justified. Using the manufacturer's original specifications to establish baseline performance should provide a conservative savings estimate because it will most likely understate the savings. New chiller performance could be based on manufacturer's specifications or a factory test. If at all possible, new chiller performance should be validated by observing operating characteristics during the commissioning phase. Operating hours and load profiles can be based on the results of reliable chiller logs, EMCS records, bin hour calculations, simulation results, or other recognized and documented techniques.

For projects where savings are expected to be significantly greater than $10,000, method CH-A-02 is preferred. Monitoring of the existing chiller during the Detailed Energy Survey can be used to establish both performance and usage in terms of kW per ton and ton-hours per cooling-degree-day, for example. This information can be used to establish a load regression model based on weather conditions and other relevant parameters and can then be adjusted to TMY conditions and stipulated. A baseline chiller performance model can also be established and used to determine baseline performance at any operating condition. At a minimum, a one-time spot measurement of the installed chiller should be used to verify performance. (Note: it may be necessary to use ASHRAE's bi-quadratic model to adjust performance to conditions used in equipment ratings.) Short-term monitoring during the commissioning phase is preferable to spot measurements in order to show that the actual chiller performance curve emulates the manufacturer's ratings.

## 5.6 BOILER REPLACEMENT OR IMPROVEMENT

Although the FEMP Guidelines do not explicitly discuss methods for boiler replacement or efficiency improvement, stipulated load values may be used for this (and similar) measures. In general, boiler efficiencies (pre- and post-retrofit) need to be quantified through measurements. Although manufacturer's specifications may be a source of boiler efficiencies, they may be misleading for existing equipment due to degradation and lack of tuning. Option A for boilers is MVP-compliant if boiler performances are measured.

Acceptable sources of stipulated heating loads include the following (in order of preference):

- Fuel consumption records along with concurrent (TMY) weather data after accounting for baseline system efficiency
- Building simulation results (if calibrated to existing or installed system)
- Engineering calculations
- Boiler logs along with concurrent weather data.

These sources of information have significant limitations that should be recognized. Fuel consumption records are usually monthly records, which makes it more difficult to correlate heating load to weather conditions. (Monthly fuel consumption records are often not coincident with summarized weather data. The accuracy of regression models of fuel consumption as a function of monthly heating degree-days suffer as a result.) The presence of other fuel-operated equipment must also be considered. Fuel use records implicitly include boiler and heating system efficiencies that must be accounted for. Heat delivered will be a function of existing system efficiency—both boiler and distribution equipment (steam, hot water). Building simulation models of the baseline case should first be calibrated to actual weather conditions, which can be difficult and expensive. Engineering calculations may oversimplify the building envelope model or not accurately represent other factors (e.g., solar and internal gains, human behavior, infiltration). Boiler logs sometimes only indicate run-times and operating conditions, so load information may not always be available.

If monitoring data is available for one year or more (EMCS or other records of steam or hot water production), it may be preferable to develop regression models of heating load as a function of weather conditions and then adjust the results to typical weather conditions. Where adequate fuel consumption records exist and fuel use can be isolated, it may be preferable to use an Option C (utility bill analysis) approach instead of Option A or B.

Boiler performance can vary significantly from design specifications depending on condition, installation, and tuning. Therefore, periodic measurement of boiler system performance should be considered.. Measuring boiler system performance has value to the owner as it can be used to optimize the system, for diagnostics, and for scheduling maintenance.

### 5.6.1 Recommended Practice for Boiler Replacement or Improvement

Stipulating boiler performance is never recommended. At a minimum, baseline boiler performance (combustion efficiency) should be established through a simple one-time measurement of temperatures and stack gas composition. Engineering calculations can be used to determine system efficiency once combustion efficiency has been established. Similar procedures should be followed in the post-retrofit case. Where furnaces or heat pumps are replacing a steam plant, the distribution efficiency (steam and heat loss) needs to be considered as well.

Usage may be stipulated as discussed previously and adjusted to TMY weather conditions. Fuel use regression models, engineering calculations, bin-hour calculations, and simulation modeling are all acceptable methods of estimating heating loads and system usage.

### 5.7 ENERGY MANAGEMENT AND CONTROL SYSTEM UPGRADES

Although the FEMP guidelines do not explicitly discuss methods for EMCS upgrades, stipulated operating hours, thermostat setpoints, and weather conditions may be used to estimate savings. For example, savings may be based on reduction in fan motor run-times, reduction in outside air intake, using temperature setbacks/setups, adding air-side economizing, or other changes in the operating characteristics of the HVAC system. Since there are many possible combinations of energy-conservation strategies, using stipulated values for an EMCS measure may not capture all of the potential savings. Option A for an EMCS is MVP-compliant only if at least one parameter (usage or performance) is measured.

As with any M&V method that relies on stipulated values, the source of the stipulations needs to be explicitly defined. Once the existing and proposed control strategies have been identified, the defining equations need to be developed so that the relevant parameters can be established. Sources of these values may include the following (in order of preference):

- Proposed control system logic for operation of equipment (operations schedules, etc.)
- Current control strategies or run-time schedules based on lack of control (e.g., fans operate continuously)
- Temperature bin-hours based on TMY or real weather data
- Results from calibrated building simulation models

Given that the purpose of an EMCS is to collect and process data, the decision to stipulate post-installation parameters (other than weather data) should be avoided unless significant reasons are present. Savings are the result of changes to operating strategy; additional savings can often be obtained through ongoing commissioning and optimization. The EMCS itself is the source of this information—additional hardware should not be required. For large projects, information obtained from the EMCS should be used in preference to stipulated values whenever practical. However, it is acceptable to base performance and savings on typical weather conditions by adjusting monitored performance or the baseline.

It is impossible to describe all of the ways that an EMCS can be used to improve performance. Table 5-2 gives some examples of possible savings and their relevant parameters.

Table 5-2: Potential EMCS energy-saving strategies.

| EMCS Strategy | Relevant Parameters |
|---|---|
| Reduce equipment run-time; savings from reduced usage only | Equipment power, pre- and post-retrofit operating schedules. |
| Reduce equipment run-time; savings from reduced equipment usage and reduced outside air use | Equipment power, pre- and post-retrofit operating schedules, outside air flow, outside air temperature, delivered air temperature or space temperature. |
| Temperature setback/setup; savings from reduced heating and cooling loads | Temperature setpoints, weather conditions, building thermal losses. May be desirable to evaluate with simulation model. |
| Air-side economizing | Number of hours air-side economizing can displace mechanical cooling, mechanical cooling demand during those hours. May be desirable to evaluate with simulation model. |
| Hot and cold deck temperature reset | Current and proposed hot and cold deck temperatures, airflow, outside air temperatures. May be desirable to evaluate with simulation model. |

The above list illustrates that altering one parameter such as equipment run-time can have multiple effects that need to be considered. The parameters to be controlled and the parameters that are affected need to be identified and then measured or verified. Performance verification can be conducted through annual inspections or data trending to show that the control sequences are operating as intended and by calibrating sensors.

### 5.7.1 Recommended Practice for Energy Management and Control System Upgrades

Since EMCS measures encompass a broad variety of savings opportunities, it is difficult to generalize recommended practices. Option A methods are not always appropriate, and post-installation operating parameters should be measured wherever practical. Stipulations are intended to reduce M&V costs to levels consistent with project risk and to allocate risk to the appropriate party. For example, an EMCS designed to schedule an air handler that currently operates continuously can safely stipulate the baseline and post-retrofit usage characteristics. Where savings are in excess of $10,000, it would be desirable to measure the controlled load, such as motor demand on a sample of the air-handler motors. For other strategies, it is appropriate to stipulate the usage characteristics and to measure a sample of the factors that affect performance. In all cases, the equations, methods, and source data used to estimate and verify the savings need to be presented in the M&V plan and the annual reports.

## *5.8 Water-Conservation Measures*

Option A methods WCM-A-01 and WCM-A-02 assume that the agency and the ESCO are confident that unit water consumption can be reliably estimated and stipulated for each fixture type and that device usage (flushes per month, hours of use, water use schedule, or other parameter) can be quantified and stipulated based on occupancy and schedules (WCM-A-01) or short-term metering (WCM-A-02). These methods are appropriate for projects in which water is conserved in one or both of these ways: (1) replacing existing plumbing fixtures with new fixtures designed to deliver water at low flow rates, or (2) delivering water during fewer and/or shorter intervals. Method WCM-A-01 is not MVP-compliant; WCM-A-02 is.

These two methods are applicable to low-flush toilets and urinals, showerheads, dishwashers, laundry, and removal of once-through devices, because of the relative ease with which performance can be quantified.

Acceptable sources of performance information include manufacturer's specifications for gallons per flush, gallons per load, or gallons per minute (GPM). If such information is not available, spot measurements of gallons per cycle or gallons per hour will need to be taken. Sources for usage information can come from utility data, usage logs, laundry records, or from observations of occupant behavior.

### 5.8.1 Recommended Practice for Water-Conservation Measures

For many projects, method WCM-A-01 is probably appropriate even though it is not MVP-compliant. Actual water consumed in gallons per flush (toilets), GPM (showerheads, aerators), or gallons per load (washers) for new equipment should be reasonably close to manufacturer's specifications. It may be acceptable to rely on verifying the *potential to perform* instead of measuring such ratings. There is probably greater uncertainty in the baseline fixture use, as toilet control valves may leak and the population of existing showerheads may behave differently than rated or assumed.

For projects where expected savings exceed $10,000 per year, it is recommended that method WCM-A-02 be used where performance measurements are taken on a sample of the existing equipment, especially on easily measured devices such as showerheads.

Where stipulated usage factors are to be used (WCM-A-01), identify the source of the information used to support those values. Regardless of how performance is determined, Option A methods for water conservation generally use stipulated values for frequency of use of the equipment. It is important not to overestimate the overall water use.

For *any* project where energy savings from hot water reductions will be claimed, spot measurements of the cold water temperature and the hot water cycle temperature (shower, washer, dishwasher, etc.) should be made and used to support the energy savings estimates. Energy savings are related to the temperature difference between incoming (cold) water and supply (hot) water in addition to water consumption.

## *5.9 NEW CONSTRUCTION*

Option A method NC-A-01 is to be used for new construction projects in which the potential to perform needs to be verified, but baseline performance is stipulated. (Currently federal ESPCs can be used for incremental efficiency improvements to new construction, but not for overall construction costs.) Performance should be physically verified following construction. Method NC-A-01 is MVP-compliant only if at least one parameter is measured.

Use of this method for Federal buildings requires that the baseline be defined per federal rule 10 CFR 434 and 435, which requires residential buildings to comply with the Model Energy Code 1992 and all others to comply with ASHRAE 90.1-1989. If local codes are more stringent, such as California's Title 24, these codes take precedence. Only savings that exceed the applicable standard can be claimed. Since codes cover both envelope and equipment performance, the only practical means of defining baseline performance is through engineering analysis or building simulation modeling. Results can then be used as the stipulated baseline performance, either for the entire building or for the affected equipment. Building simulation and building commissioning are both sophisticated exercises, and significant attention should be paid to ensuring that the building meets or exceeds its performance criteria. This typically precludes the use of stipulations in particular and Option A methods in general.

However, where the proposed ECM is limited to a small and definable segment of the new construction project, an Option A approach may be appropriate instead. For example, consider the installation of efficient lighting or an efficient chiller that exceeds applicable energy codes. An Option A approach could be followed similar to that of LE-A-01 or -02 or CH-A-01 for a new construction project using the code lighting density or code chiller performance values as the baseline.

Following construction, the *potential to perform* still needs to be verified. This can be done through short-term monitoring of installed equipment or total energy use. For example, chiller savings for a new construction project would require verification that it was operating on the manufacturer's performance curve *and* that the performance curve exceeds the applicable code value. If these conditions are met, then savings can be estimated by using TMY weather data to determine new equipment performance and comparing it to the baseline scenario.

#### 5.9.1 Recommended Practice for New Construction

Option A for new construction should only be used where the proposed measure affects a definable section of the new construction project that can be characterized without building modeling. For projects where savings will come from the installation of efficient equipment instead of standard equipment, the baseline performance should be set at standards as defined in 10 CFR 434 and 10 CFR 435. These regulations codify the Model Energy Code of 1992 for residential buildings and ASHRAE 90.1-1989 for nonresidential buildings. Where more rigorous codes are in effect such as California's Title 24, these take precedence.

Installed equipment should be measured to verify performance claims and to ensure proper commissioning. Usage can be based on stipulated typical conditions for reporting savings. To implement this, the measured performance will most likely have to be adjusted to typical conditions.

### *5.10 Operations and Maintenance Savings*

Savings due to reductions in operations and maintenance (O&M) expenditures resulting from energy-efficiency projects can be claimed in ESPC projects. O&M savings are defined rather broadly and can assume the following forms:

- Parts and labor cost reductions as a result of replacing old and unreliable equipment
- Parts and labor cost reductions as a result of installing standardized equipment
- Parts and labor cost reductions because the ESCO will assume O&M responsibilities

Energy and water savings due to changes in O&M practices (e.g., a steam trap maintenance program) should be treated as energy and water savings.

Methods for estimating O&M savings resulting from changes to equipment have not been developed for the FEMP or MVP guidelines. However, the general rule to follow is that any savings claimed from O&M activities must result in a real decrease in expenditures. Operations & maintenance budget baselines cannot be based on what the agency *should* be spending for proper O&M; baseline expenditures *must* be based on the agency *is* spending. The agency's O&M expenditures after implementation need to decrease for savings to be considered real. The MVP does not address cost savings due to O&M savings.

If the ESCO is offering future O&M services for a specified fee (effectively stipulating the new cost), the baseline budgets may be stipulated if they are from the following:

- An existing service contract that will be eliminated,
- An existing labor budget if staff reductions are planned,[4]
- Documented expenditures for replacement parts or service calls.

Stipulated baseline budgets and service contract fees may be escalated to account for inflation during the contract term. Escalation rates need to be documented and should come from sources such as the National Institute of Standards and Technology, which estimates such factors for life-cycle costing.

Operations & maintenance savings as a result of upgrading existing equipment are sometimes more difficult to estimate, especially if savings are targeted at a specific technology. The agency will need to quantify its parts and labor costs for a particular system or service—an exercise that may prove difficult if service records are not kept or if existing O&M practices are substandard. Costs for replacement parts can often be determined from purchase records and annualized to arrive at a baseline value. Labor costs for particular services may be more difficult to quantify since service records may not be representative or may lack sufficient detail.

For example, parts costs for replacement light bulbs, ballasts, or steam traps are relatively easy to quantify from purchase records. Labor costs to replace lamps, ballasts, or steam traps are more difficult to quantify because time spent on these specific tasks may not be well documented. Additionally, labor reductions on these specific tasks may not qualify as "real savings" if the labor budget does not decrease. Although the agency receives value in the sense that labor is freed up to perform other useful tasks, this value may not result in cost savings that can be paid to the ESCO.

### 5.10.1 Recommended Practice for Operations and Maintenance Savings

Baseline O&M expenditures should be based on actual budgets and expenditures to the greatest extent practical. This essentially "measures" the baseline consumption of these services. Estimated and stipulated expenditures should be avoided if at all possible. In cases where such information is not available and must be estimated, parts and labor estimates may need to be derived from resources such as R.S. Means or ASHRAE methods. Expenditures should be adjusted to reflect the actual labor rates.

[4] This is an extremely sensitive issue. Will reductions-in-force be due to attrition & retirement, reassignment, or termination? At what rate will staff be eliminated or transferred? Both the ESCO and agency need to proceed cautiously if staffing reductions are required.

### 5.11 ON-SITE GENERATION

FEMP guidelines have not been thoroughly developed for generation and cogeneration systems. Because of the numerous issues associated with energy cost, utility time-of-use and peak demand rates, O&M, grid interconnection, and reliability, Option A methods are generally not appropriate for on-site generation. Inputs and outputs of generation and cogeneration systems are typically measured directly using Option B or C methods. The MVP does not directly address on-site generation.

#### 5.11.1 Recommended Practice for On-Site Generation

Option A is not recommended for on-site generation projects.

### 5.12 RENEWABLE ENERGY SOURCES

Renewable sources provide energy that will supplement or displace conventional energy sources. Renewable sources include solar (thermal, electrical, daylighting), wind (electrical), biomass (electrical and thermal), and microhydro systems(electrical). Quantifying the benefits from renewable energy systems requires measuring or estimating the net energy produced and valuing it at the rate of energy displaced or avoided. Increased O&M costs (if any) must also be considered.

The FEMP M&V methods for renewable energy projects in *M&V Guidelines 2.2* are presently very general and are being refined (see Draft Renewable Energy Guide at http://ateam.lbl.gov/mv). However, two approaches are suggested for renewable energy projects: one-for-one replacement and net energy use. Both of these methods can use stipulated values in conjunction with verification activities. One-for-one replacement methods assume that any energy produced will immediately displace conventional energy sources. The energy savings are valued at the conventional energy rate. Net energy use considers the total energy consumption over time with and without the renewable energy system. Option A methods for renewable energy sources are MVP-compliant only if at least one parameter is measured.

For both approaches, the energy produced can be estimated from established engineering techniques or simulation modeling using TMY weather data or other resource assessment data as the stipulated condition. Verification activities to demonstrate potential to perform should involve short-term metering to show that energy production rates agree with estimated values under similar weather (or other) conditions. Energy production from renewable energy systems can be estimated by using results from the following (in no particular order):

- Engineering analysis of monthly solar resource and weather conditions, coupled with equipment specifications and estimated loads
- Bin analysis (hourly or 15-minute, but not daily or average) of wind speeds and turbine outputs
- BIPV Designer (photovoltaic)
- DOE2.1, EnergyPlus, or BLAST (solar thermal space heating)
- Energy 10 (passive solar and daylighting)
- F-Chart method (solar domestic hot water)
- TRNSYS (solar thermal and domestic hot water)

Most of these techniques or computer programs can estimate renewable energy production for specific locations using TMY weather data or data published by the National Renewable Energy Laboratory's (NREL's) Renewable Resource Data Center.

Verification of energy production should be based on short-term metering (one day to one week) to show that energy output from the installed system matches that predicted from the estimating technique over a range of resource availability conditions. For example, the output of a photovoltaic system could be monitored while concurrently monitoring solar radiation levels. Photovoltaic output can then be compared to the estimated values to show that the system is working as predicted.

### 5.12.1 Recommended Practice for Renewable Energy Sources

The output of renewable energy systems will vary with resource availability, which is often weather-dependant. It is appropriate to stipulate resource availability based on TMY weather data or NREL's resource database. In most cases, the output of renewable energy systems should be submetered (an Option B approach), but it is acceptable to adjust the measured output to reflect periods of unusual weather patterns and normalize them to typical conditions.

## APPENDIX: CALCULATING UNCERTAINTY

### Background

Performing and understanding statistical calculations seems to be the greatest barrier to making informed decisions. A better understanding of statistics begins with some definitions and explanations. Accuracy is the extent to which we know a measurement to represent the 'true' value; precision indicates the repeatability of a measurement. Accuracy and precision are not the same[5], but a high precision usually indicates a high degree of accuracy. For M&V purposes, accuracy is assured by proper calibration of measurement instruments while precision is related to the number of measurements made. Uncertainty is the extent to which the true value remains unknown and is a function of both measurement accuracy and precision.

Because it is impractical to measure all parameters and all equipment in an energy efficiency project, sampled measurements are used and the results extrapolated to the population. This makes measurement repeatability—precision—the greatest contributor to uncertainty. By taking multiple measurements, we hope to arrive at the 'true' value of the measured population (assuming our instruments are perfectly accurate). However, we also need to know the confidence of the measurement—the probability that the measured samples represent the entire population. For any set of measurements, there is a tradeoff between precision and confidence level; precision can only be increased by sacrificing confidence. To increase both precision and confidence requires taking additional measurements.

When discussing precision and confidence levels, both need to be specified together. A stated objective of 20% precision and 80% confidence indicates that our measurement should be within 20% (+/-) of the true value and that there is an 80% chance that we have selected representative samples from our population. (We will be within 20% of the true value 80% of the time.) Using the same number of samples but stating that our confidence level is 90% reduces the precision (increases the uncertainty) to 26%. The actual confidence and precision of a set of measurements can only be made after the fact and should be calculated and compared to the original objective.

Appendix D of the FEMP M&V Guidelines discuss measurement uncertainty and provide equations to calculate sample size to achieve desired precision and confidence levels. Table D-2 provides sample sizes to achieve specific precision and confidence levels for lighting operating hour measurements. Table D-2 is based on an *assumed* coefficient of variation ($C_v$) of 0.5. This is usually a safe value to assume for lighting operating hour measurements (based on experience) but may not be applicable to other parameters or technologies. For example, lighting operating hours where motion sensors are used may have a higher variation and require more samples than the table indicates. Lighting fixture powers have a much lower variation and require significantly fewer samples to achieve desired confidence and precision levels. The sample sizes in table D-2 are not absolute; they are recommendations to use as a starting point. The actual precision and confidence levels for any set of measurements *always* needs to be calculated after the fact to show that the sampling objectives have been met.

[5] Consider a ruler that has the first 1" removed. Measurements made with this ruler will be precise (repeatable) but not accurate (truthful).

**Example**

To move the discussion of uncertainty from the abstract to the practical, consider a lighting retrofit project. Two parameters determine the savings: reduction in fixture power and operating hours. Measuring operating hours requires a one-time measurement whose uncertainty is a function of the sample size (number of measurements taken). To achieve 20% precision in the operating hours at an 80% confidence interval would require monitoring up to 11 points for each group; more if the standard deviation of the measurement is large ($C_v$ greater than 0.5); less if the standard deviation of measurement is low ($C_v$ less than 0.5). On the other hand, fixture power reduction is based on the difference between the existing fixtures and the proposed fixtures. Lighting fixture powers can be based either on measurements (low uncertainty) or on estimated values from lighting tables (greater uncertainty). The uncertainty in each estimate or measurement contributes to the overall uncertainty. But how much uncertainty do lighting tables introduce to the savings estimate? Even though lighting tables may list fixture powers to within 10% of their expected values[6], energy savings are proportional to the *difference* between the existing and the proposed fixture powers. For example, a commonly used lighting table shows that a 2-lamp, 4-foot fluorescent fixture with F40T12 lamps and a magnetic ballast draws 86 W and a 2-lamp, 4-foot fixture with F32T8 lamps and an electronic ballast draws 60 W. Because the actual fixture power may be +/– 10% of the rated power, the baseline fixture power could be between 77 W and 95 W while the new fixture power could be between 54 W and 66 W. The possible demand reductions values could be any of the following:

86 W – 60 W = 26 W (expected value)

77 W – 54 W = 23 W

77 W – 66 W = 11 W (minimum value)

95 W – 54 W = 41 W (maximum value)

95 W – 66 W = 29 W

This suggests that the expected demand reduction of 26 W is only within 15 W of the possible range of values. The correct way to calculate the total uncertainty is to take the square root of the sum of the squared uncertainties as follows:

$$[\,(86\text{ W} \times 10\%)^2 + (60\text{ W} \times 10\%)^2\,]^{1/2} = 10.5\text{ W uncertainty}$$

$$[10.5\text{ W uncertainty}\,] / [26\text{ W demand reduction}] = 40\%$$

So the uncertainty in the estimated demand reduction is not the uncertainty of the lighting table (10%), but 10 W out of 26 W, *or 40% of the demand reduction*. Reducing the uncertainty in the demand reduction to 20% *requires* that the baseline and new fixture powers be measured to 5% precision. The actual number of fixture types to be measured will be a function of the measurement standard deviation, but three to six measurements per fixture type should provide a measurement with 5% precision at 80% confidence. (This assumes that the standard deviation is 6% to 10% of the measurement average or that the coefficient of variation is between 0.06 and 0.10.) For all measurements, the actual precision of the measurement should be calculated to see

[6] This is not a documented value but one based on judgement and experience. An 80% confidence level is assumed.

whether the desired precision criterion has been met. If not, more measurements should be taken until it is.

The accumulation of sampling uncertainty contributes to the overall uncertainty in the savings estimate. If power measurements are made to 5% precision, the uncertainty in the demand reduction will be on the order of 20%. If this is combined with operating hour measurements made to 20% precision, the overall uncertainty in the savings estimate is 28%. (All at 80% confidence level).

Appendix D of the FEMP *M&V Guidelines* discusses sampling statistics and uncertainty analysis in more detail. Additional guidance can be found in American Society of Heating, Refrigeration, & Air-Conditioning Engineers (ASHRAE) Guideline 14 (2002).