EVO

EFFICIENCY VALUATION ORGANIZATION

International Performance Measurement and Verification Protocol

Core Concepts

Prepared by Efficiency Valuation Organization
www.evo-world.org

June 2014

EVO 10000 – 1:2014

EVO Vision

A global marketplace that correctly values the efficient use of natural resources and utilizes end-use efficiency options as a viable alternative to supply options

EVO Mission

To develop and promote the use of standardized protocols, methods and tools to quantify and manage the performance risks and benefits associated with end-use energy-efficiency, renewable-energy, and water-efficiency business transactions

Contents Page

Acknowledgements

The IPMVP is primarily maintained by the following volunteers. EVO appreciates their work in receiving comments and developing changes for the 2014 Core Concepts edition. EVO appreciates the support and commitments made by the employers of all EVO volunteers.

EVO Board of Directors and Officers (2014)

Thomas Dreessen, **Chair** (USA), EPS Capital

Pierre Langlois, **Vice-Chair** (Canada) Econoler

John Stephen Kromer, **Treasurer** (USA), Independent Consultant

John Cowan, **Secretary** (Canada), Environmental Interface Limited

Anees Iqbal, (UK), Maicon Associates Ltd.

Patrick Jullian (France), GIMELEC

Tienan Li (China), Center for Industrial Energy Efficiency (CIEE)

IPMVP Committee (2014)

Ellen Franconi, **Chair** (USA), Rocky Mountain Institute

David Jump, **Vice-Chair** (USA,) Quantum Energy Services & Technologies, Inc. (QuEST)

Thomas Adams (USA), AFCESA

Raja Chirumamilla (USA), Sain Engineering Associates, Inc.

Shankar Earni (USA), Lawrence Berkeley National Laboratory

LJ Grobler (South Africa), Energy Cybernetics Pty Ltd.

Sami Khawaja (USA), Cadmus Group Inc.

Raj Khilnani (India), Freelance Energy Consultant

David Korn (USA), Cadmus Group Inc.

Ken Lau (Canada), BC Hydro

Daniel Magnet (Switzerland), IBTECH

Fernando Milanez (Brazil), INEE

Tracy Phillips (USA), 7th Gen Energy Solutions

Rafael Poquet (Spain), Freelance Energy Consultant

Guruprakash Sastry (India), Infosys Limited

Vilnis Vesma (UK), Degrees Days Direct Limited

Phil Voss (USA), National Renewable Energy Lab

Kevin Warren (USA), Warren Energy Engineering

Lia Webster (USA), Portland Energy Conservation Inc. (PECI)

Max Zhang (China), SGS-CSTC Standards Technical Services Co., Ltd.

Organizational Subscribers:

EVO also appreciates the financial support made by its Organizational Subscribers. A current list is provided on the back cover of this document.

Foreword

This International Performance Measurement and Verification Protocol (IPMVP®) is owned and published by the Efficiency Valuation Organization (EVO®), a non-profit private corporation. EVO envisions a global marketplace that correctly values the efficient use of natural resources and utilizes end-use efficiency as a viable alternative to new energy supply. EVO's mission is to develop and promote standardized methods to quantify and manage the risks and benefits associated with business transactions on end-use energy efficiency, renewable energy, and water efficiency. EVO is a subscriber-based organization with supporters around the world.

EVO is grateful to its volunteers who develop and maintain EVO documents.

EVO maintains a website (www.evo-world.org) which contains a variety of resources.

IPMVP presents common principles and terms that are widely accepted as basic to any good M&V process. It does not define the M&V activities for every application. Each project must be individually designed to suit the objectives and desired accuracy of energy- or water-saving efforts. This individual design is recorded in the project's M&V Plan and savings are reported as defined by that M&V plan.

IPMVP promotes efficiency investments by the following activities:

a) Documentation of common terms and methods to evaluate performance of efficiency projects for buyers, sellers and financiers. Some of these terms and methods may be used in project agreements, though IPMVP does not offer contractual language.

b) Providing methods with different levels of cost and accuracy for determining savings either for the whole facility or for individual energy conservation measures (ECM).

c) Specifying the contents of a Measurement and Verification Plan (M&V Plan). This M&V Plan adheres to widely-accepted fundamental principles of M&V and should produce verifiable savings. An M&V Plan must be developed for each project by a qualified professional, such as a Certified M&V Professional (CMVP ®).

d) Ensuring applicability to a wide variety of facilities including existing and new buildings and industrial processes.

This document defines the core concepts and principles of M&V, describes M&V plan requirements, and describes retrofit isolation and whole building M&V options and methods. Finally, it describes the requirements of M&V reports. These requirements are necessary to meet IPMVP's core principles and for a project to be considered adherent with IPMVP.

IPMVP Core Concepts

1 Scope

Efficiency Valuation Organization (EVO) publishes the International Performance Measurement and Verification Protocol (IPMVP) and related documents to increase investment in energy and water efficiency, demand management and renewable energy projects around the world.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

This section is maintained for potential future use. At this time there are no normative references to IPMVP Core.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply:

3.1 Adjustments

Increments in consumption or demand of the baseline or the reporting periods as a consequence of applying a common set of conditions to address simple comparison of demand or consumption before and after implementation of an energy conservation measure (3.3).

NOTE: Adjustments must account for the differences in conditions between the baseline and reporting periods.

3.2 Baseline

Energy performance measured before energy performance improvement actions are implemented.

3.3 Energy conservation measures - ECM

Measures to improve efficiency or conserve energy or water, or manage demand.

3.4 Independent variable

A parameter that is expected to change routinely and have a measurable impact on energy use of a system or facility.

3.5 Measurement and verification - M&V

The process of using measurement to reliably determine actual *savings* (3.7) created within an individual facility by an energy management program. This is also known as "**MRV"** - measurement, report, and verification.

3.6 Operational verification

Confirmation of the potential to achieve savings

3.7 Savings

Value for energy, water or demand determined by comparing measured use or demand before and after implementation of a programme, making suitable adjustments for changes in conditions

4 Principles

4.1 General

The following sections list the key principles of IPMVP. These principles provide the basis for assessing the adherence of an M&V process to IPMVP.

4.2 Accurate

M&V reports should be as accurate as can be justified based on the project value. M&V costs should normally be small relative to the monetary value of the savings being evaluated. M&V expenditures should also be consistent with the financial implications of over- or under-reporting of a project's performance. Accuracy trade-offs should be accompanied by increased conservativeness with increased use of estimates and judgements. In addition, accuracy can be influenced by the level of adjustment of energy quantities made to the reporting-period conditions or to some other set of conditions. Accuracy can also be affected by the duration of the baseline period and the reporting period.

4.3 Complete

The reporting of energy savings should consider all effects of a project. M&V activities should use measurements to quantify the significant effects, while estimating others.

4.4 Conservative

Where judgements are made about uncertain quantities, M&V procedures should be designed to under estimate savings.

4.5 Consistent

The reporting of a project's energy effectiveness should be consistent across:

- different types of energy efficiency projects;
- different energy management professionals for any one project;
- different periods of time for the same project; and
- energy efficiency projects and new energy supply projects.

4.6 Relevant

The determination of savings should measure the performance parameters of concern, or least well known, while other less critical or predictable parameters may be estimated.

4.7 Transparent

All M&V activities should be clearly and fully disclosed. Full disclosure should include presentation of all of the elements defined for the contents of an M&V Plan and a savings report, respectively.

5 IPMVP Framework

5.1 General

Good M&V practice is well integrated into the process of identifying, developing, procuring and installing energy conservation measures. IPMVP's framework requires certain activities to occur at key points in this process, and describes other important activities that must be included in good M&V practice. This section describes the elements of IPMVP's framework.

5.2 Operational Verification

Operational verification serves as a low-cost initial step for realizing savings potential and should precede savings verification activities. Operational verification is not the responsibility of the independent verifier but should be included as part of a performance contract.

A range of operational verification methods are outlined in Table 1. Selection of a given approach depends on the ECM's characteristics as noted in the table.

For independent review of reported savings, the verifier shall satisfy himself that the ECM is based on sound scientific principles and that independent evidence exists to support any ex-ante claims made for its efficacy.

Table 1 — Operational Verification Approach

Operational verification approach	Typical ECM application	Activities
Visual Inspection	ECM will perform as anticipated when properly installed: direct measurement of ECM performance is not possible.	View and verify the physical installation of the ECM.
Sample Spot Measurements	Achieved ECM performance can vary from published data based on installation details or component load.	Measure single or multiple key energy –use parameters for a representative sample of the ECMs installations.
Short-Term Performance Testing	ECM performance may vary depending on actual load, controls or interoperability of components.	Test for functionality and proper control. Measure key energy use parameters. May involve conducting test designed to capture the component operating over its full range or performance data collection over sufficient period of time to characterize the

		full range of operation.
Data Trending and Control-Logic Review	ECM performance may vary depending on actual load and controls. Component or system is being monitored and controlled through BAS or can be monitored through independent meters.	Set up trends and review data or control logic. Measurement period may last for a few days to a few weeks, depending on the period needed to capture the full range of performance.

5.3 Savings verification

5.3.1 Measurement boundary

Savings may be determined for an entire facility or simply for a portion of it, depending upon the purposes of the reporting.

- If the purpose of reporting is to help manage only the equipment affected by the savings program, a measurement boundary should be drawn around that equipment. Then significant energy requirements of the equipment within the boundary can be determined. The approach used is the retrofit-isolation options. Determination of energy may be by direct measurement of energy flow or by direct measurement of proxies of energy use that give direct indication of energy use.

- If the purpose of reporting is to help manage total facility energy performance, the meters measuring the supply of energy to the total facility can be used to assess performance and savings. The measurement boundary in this case encompasses the whole facility. The approach used is the whole-facility Option C.

- If baseline or reporting period data are unreliable or unavailable, energy data from a calibrated simulation program can take the place or the missing data, for either part or all of the facility. The measurement boundary can be drawn accordingly. The calibrated simulation Option D is the approach used.

- Some of the energy requirements of the systems or equipment being assessed may arise outside a practical measurement boundary. Nevertheless, energy effects of the ECM(s) should be considered. Those energy effects that are significant should be determined from measurements, the rest being estimated or ignored.

- Any energy effects occurring beyond the notional measurement boundary are called interactive effects or leakages. The magnitude of these interactive effects needs to be estimated or evaluated in order to determine savings. Alternatively, they may be ignored as long as the M&V plan includes discussions of each effect and its likely magnitude.

5.3.2 Measurement period selection

5.3.2.1 Baseline period

Care should be taken in selecting the baseline period. The baseline period should be established to:

a) represent operating modes of the facility - the period should span a full operating cycle from maximum energy use to minimum;

b) fairly represent operating conditions of a normal operating cycle;

c) include only time periods for which fixed and variable energy-governing facts are known about the facility.

NOTE 1 The extension of baseline periods backwards in time to include multiple cycles of operation requires equal knowledge of energy-governing factors throughout the longer baseline period in order to properly derive routine and non-routine adjustments after ECM installation.

d) coincide with the period immediately before commitment to undertake the retrofit.

NOTE 2 Period's further back in time would not reflect the conditions existing before retrofit and may therefore not provide a proper baseline for measuring the effect of just the ECM.

e) support ECM planning.

NOTE 3 ECM planning may require study of a longer time period than is chosen for the baseline period. Longer study periods assist the planner in understanding facility performance and determining what the normal cycle length actually is.

5.3.2.2 Reporting period

The user of the savings report should determine the length of the reporting period. The reporting period should encompass at least one normal operating cycle of the equipment or facility, in order to fully characterize the savings effectiveness in normal operating modes.
Some projects may cease reporting savings after a defined test period ranging from an instantaneous reading to a year or two.

The length of any reporting period should be determined with due consideration of the life of the ECM and the likelihood of degradation of originally achieved savings over time.

Regardless of the length of the reporting period, metering may be left in place to provide feedback of operating data for routine management purposes and specifically to detect subsequent adverse changes in performance.

If reducing the frequency of performance measurement after initial proof of savings, other on-site monitoring activities could be intensified to ensure savings remain in place.

IPMVP- adherent savings can only be reported for the reporting period that uses IPMVP-adherent procedures. If IPMVP- adherent savings are used as a basis for assuming future savings, future savings reports do not adhere to IPMVP.

5.3.2.3 Adjacent measurement periods (on/off test)

When an ECM can be turned on and off easily, baseline and reporting periods may be selected that are adjacent to each other in time. A change in control logic is an example of an ECM that can often be readily removed and reinstated without affecting the facility.

Such "on/off tests" involved energy measurements with the ECM in effect, and then immediately thereafter with the ECM turned off so that pre-ECM (baseline) conditions return. The difference in energy use between the two adjacent measurements periods is the savings created by the ECM. Savings is calculated without adjustments if the energy-influencing factors are the same in the two adjacent periods.

Savings = (Baseline period consumption or demand - reporting period consumption or demand)

This technique can be applied under both retrofit isolation and whole-facility options. However measurement boundaries must be located so that it is possible to readily detect a significant difference in metered energy use when equipment or systems are turned on and off.

The adjacent periods used for the on/off test should be long enough to represent stable operation. The periods should also cover the range of normal facility operations. To cover the normal range, the on/off test may need to be repeated under different operating modes such as various seasons or production rates.

ECMs that can be turned off for such testing may be at risk of being accidently or maliciously turned off when intended to be on. Efforts should be taken to ensure the persistence of such ECMS.

5.3.3 Basis for adjustment

The adjustment term should be computed from identifiable physical facts about the energy governing characteristics of equipment within the measurement boundary. Two types of adjustments are possible:

a) Routine adjustments – For any energy governing factors expected to change routinely during the reporting period (such as weather or production volume), a variety of techniques can be used to define the adjustment methodology. Techniques may be as simple as a constant value (no adjustment) or as complex as a several multiple parameter non-linear equations each correlating energy with one or more independent variables. Valid mathematical techniques must be used to derive the adjustment method for each M&V plan.

b) Non-routine adjustments – For those energy governing factors which are not usually expected to change, (such as: the facility size, the design and operation of installed equipment, the number of weekly production shifts, or the type of occupants) the associated static factors must be monitored for change throughout the reporting period.

Therefore savings is more fully expressed as:

Savings = (Baseline Energy – Reporting Period Energy) ± Routine Adjustments ± Non-Routine Adjustments

The adjustments are used to modify the measured energy data to reflect the same set of conditions as the baseline. The mechanism of the adjustments depends upon whether savings are to be reported on the basis of the conditions of the reporting period, or normalized to some other fixed set of conditions.

5.3.4 Reporting period basis or avoided energy use

When savings are reported under the conditions of the reporting period, they can also be called avoided energy use of the reporting period. Avoided energy use quantifies savings in the reporting period relative to what energy use would have been without the ECM(s). When reporting savings under reporting-period conditions, baseline period energy needs to be adjusted to reporting period conditions. For this common style of savings reporting can be stated as:

> **Savings (avoided energy use) = (Baseline Energy± Routine Adjustments to Reporting Period Conditions ± Non-Routine Adjustments to Reporting Period Conditions) – Reporting Period Energy**

This equation is often simplified to:

> **Savings (Avoided Energy Use) = Adjusted Baseline Energy – Reporting Period Energy ± Non-Routine Adjustments to Reporting Period Conditions**

Where adjusted baseline energy is the baseline energy plus any routine adjustments needed to adjust it to the conditions of the reporting period.

The adjusted baseline energy is normally found by first developing a mathematical model which correlates actual baseline energy data with appropriate independent variable(s) in the baseline period. Each reporting period's independent variable(s) are then inserted into this baseline mathematical model to produce the adjusted baseline energy use.

5.3.5 Fixed conditions basis or normalized savings

Conditions other than those of the reporting period may be used as the basis for adjustment. The conditions may be those of the baseline period, some other arbitrary period, or a typical, average or 'normal' set of conditions.

Adjustment to a fixed set of conditions reports a style of savings which could be called "normalized" savings of the reporting period. In this method energy of the reporting period and possibly of the baseline period are adjusted from their actual conditions to the common fixed or 'normal' set of conditions selected.

> **Normalized Savings = (Baseline Energy ± Routine Adjustments to fixed conditions ± Non-Routine Adjustments to fixed conditions) – (Reporting Period Energy ± Routine Adjustments to fixed conditions ± Non-Routine Adjustments to fixed conditions)**

The calculation of the reporting period routine adjustments term usually involves the development of a mathematical model correlating reporting period energy with the independent variables of the reporting period. This model is then used to adjust reporting period energy to the chosen fixed conditions. Further, if the fixed set of conditions is not from the baseline period, a mathematical model of baseline energy is also used to adjust baseline energy to the chosen fixed conditions.

5.3.6 What basis for adjustment or which type of savings?

Factors to consider when choosing between avoided energy use and normalized savings include:

a) Avoided energy use style of savings:

   1) are dependent upon the reporting period's operating conditions. Even though savings can be properly adjusted for phenomena such as weather, the level of reported savings depends upon the actual weather.

   2) cannot be directly compared with savings predicted under baseline conditions.

b) Normalized savings:

   1) Are unaffected by reporting period conditions since the fixed set of conditions are established once and are not changed.

   2) Can be directly compared with savings predicted under the same set of fixed conditions.

   3) Can only be reported after a full cycle of reporting period energy use, so that the mathematical correlation between reporting period energy and operating conditions can be derived

6 IPMVP Options

6.1 Overview of IPMVP options

IPMVP provides options for developing and implementing a quality M&V process. These options are related to the concept of measurement boundary described earlier. In addition, different methods of calculating savings are available. Each requires energy-use data and other parameters. This section describes IPMVP's options and methods for determining energy savings. IPMVP provides four options for determining savings (A, B, C and D). Choosing options involves many considerations including the location of the ECM measurement boundary. The energy quantities in the different savings equations can be measured by one or more of the following techniques:

a) Utility or fuel supplier invoices or reading utility meters and making the same adjustments to the readings that the utility makes;

b) Special meters isolating an ECM or portion of a facility from the rest of the facility;

   NOTE: Measurements may be periodic for short intervals or continuous throughout the baseline or reporting periods.

c) Separate measurements of parameters used in computing energy use;

d) Measurement of proven proxies for energy use;

e) Computer simulation that is calibrated to some actual performance data for the system or facility being modelled.

f) If the energy value is already known with adequate accuracy or when it is more costly to measure than justified by the circumstances, then measurement of energy may not be necessary or appropriate. In these cases, estimates may be made of some ECM parameters, but others must be measured (Option A only).

g) IPMVP provides four options for determining savings (A, B, C, and D). The choice among the options involves many considerations including the location of the measurement boundary. If it is decided to determine savings at the facility level, Option C or D may be favoured. However, if only the performance of the ECM itself is of concern, a retrofit-isolation technique may be more suitable (Option A, B, or D). Table 2 summarizes the four options that are detailed in this section.

Table 2 — Overview of IPMVP Options

IPMVP Option	How Savings Are Calculated	Typical Applications
A. Retrofit Isolation: Key Parameter Measurement Savings are determined by field measurement of the key performance parameter(s), which define the energy use of the ECM's affected system(s) or the success of the project. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the measured parameter, and the length of the reporting period. Parameters not selected for field measurements are estimated. Estimates can be based on historical data, manufacturer's specifications, or engineering judgement. Documentation of the source or justification of the estimated parameter is required. The plausible savings error arising from estimation rather than measurement is evaluated.	Engineering calculation of baseline and reporting period energy from: — short-term or continuous measurements of key operating parameter(s) and — estimated values — routine and non-routine adjustments as required.	A lighting retrofit where: 1) power draw is the key performance parameter that is measured periodically and 2) lighting operating hours are estimated based on facility schedules and occupant behaviour.
B. Retrofit Isolation: All parameter Measurement Savings are determined by field measurement of the energy use of the ECM affected system. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the savings and the length of the reporting period.	Short term or continuous measurements of baseline and reporting period energy, or engineering computations using measurements of proxies of energy uses. Routines and non-routine adjustments as required.	Application of a variable speed drive and controls to a motor to adjust pump flow. Measure electric power with a kW meter installed on the electrical supply to the motor, which reads the power every minute. In the baseline period this meter is in place for a week to verify constant loading. The meter is in place throughout the reporting period to track variations in power use.
C. Whole Facility Savings are determined by measuring energy use at the whole facility or sub-facility level. Continuous measurements of the entire facility's energy use are taken throughout the reporting period.	Analysis of whole facility baseline and reporting period (utility) meter data. Routine adjustments as required, using techniques such as simple comparison or regression analysis. Non-routine adjustments as required.	Multifaceted energy management program affecting many systems in a facility. Measure energy use with the gas and electric utility meters for a twelve month baseline period and throughout the reporting period.
D. Calibrated Simulation Savings are determined through simulation of the energy use of the whole facility, or of a sub-facility. Simulation routines are demonstrated to adequately model actual energy performance in the facility. This option usually requires considerable skill in calibrated simulation.	Energy use simulation, calibrated with hourly or monthly utility billing data. (Energy end use metering may be used to help refine input data).	Multifaceted energy management program affecting many systems in a facility but where no meter existed in the baseline period. Energy use measurement, after installation of gas and electric meters, is used to calibrate a simulation. Baseline energy use, determined using the calibrated simulation, is compared to a simulation of reporting period energy use.

6.2 Option A: Retrofit-isolation

6.2.1 General

Retrofit isolation allows the narrowing of the measurement boundary in order to reduce the effort required to monitor independent variables and static factors, when retrofits affect only a portion of the facility. However boundaries smaller than the total facility usually require additional meters at the measurement boundary. Narrow measurement boundaries also introduce the possibility of 'leakage' through unmeasured interactive effects.

Since measurement is of less than the total facility, the results of retrofit isolation techniques cannot be correlated to the facility's total energy use shown on utility bills. Facility changes beyond the measurement boundary but unrelated to the ECM will not be reported by retrofit-isolation techniques but will be included in the utility's metered consumption or demand.

Two options are presented for isolating the energy use of the equipment affected by an ECM from the energy use of the rest of the facility:

a) Option A: Retrofit Isolation: Key Parameter Measurement

b) Option B: Retrofit Isolation: All Parameter Measurement

c) Isolation metering is placed at the measurement boundary between equipment the ECM affects and equipment it does not affect.

When drawing a measurement boundary, care should be taken to consider any energy flows affected by the ECM but beyond the boundary. A method must be derived for estimating such interactive effects. However if the measurement boundary can be expanded to encompass interactive effects, there is no need to estimate them.

Apart from small estimated interactive effects, the measurement boundary defines the metering points and the scope of any adjustments, which may be used in the various forms of the savings equations. Only changes to energy systems and operating variables within the measurement boundary must be monitored to prepare the adjustments term(s) of the equation.

Parameters may be continuously measured or periodically measured for short periods. The expected amount of variation in the parameter will govern the decision of whether to measure continuously or periodically. Where a parameter is not expected to change, it may be measured immediately after ECM installation and checked occasionally throughout the reporting period. The frequency of this checking can be determined by beginning with frequent measurements to verify that the parameter is constant. Once proven constant, the frequency of measurement may be reduced. To maintain control on savings as measurement frequency drops, more frequent inspections or other tests might be undertaken to verify proper operations.

Continuous metering provides greater certainty in reported savings and more data about equipment operation. This information can be used to improve or optimize the operation of the equipment on a real-time basis, thereby improving the benefit of the ECM itself. Results from several studies have shown five to fifteen percent annual energy savings can be achieved through careful use of continuous data logging.

If measurement is not continuous and meters are removed between readings, the location of the measurement and the specifications of the measurement device should be recorded in the M&V Plan, along with the procedure for calibrating the meter being used. Where a parameter is expected to be constant, measurement intervals can be short and occasional. Where a parameter may change periodically, the occasional measurements of the parameter should happen at times representative of the normal system behaviour.

Where a parameter may vary daily or hourly, as in most building heating or cooling systems, continuous metering may be simplest. For weather dependent loads, measurements may be taken over a long enough period to adequately characterize the load pattern through all parts of its normal annual cycle (i.e. each season, and weekday/weekend) and repeated as necessary through the reporting period.

Where multiple versions of the same ECM installation are included within the measurement boundary, statistically valid samples may be used as valid measurements of the total parameter.

Portable meters may be used if only short-term metering is needed. The costs of portable meters can be shared with other objectives. However, permanently installed meters also provide feedback to operating staff or automated control equipment for optimization of systems. Added meters may also enable billing of individual users or departments in the facility.

Retrofit isolation techniques are best applied.

a) Only the performance of the systems affected by the ECM is of concern, either due to the responsibilities assigned to the parties in an energy performance contract, or due to the savings of the ECM being too small to be detected in the time available using Option C.

b) Interactive effects of the ECM on the energy use of other facility equipment can be reasonably estimated, or assumed to be insignificant.

c) Possible changes to the facility, beyond the measurement boundary, would be difficult to identify or assess.

d) The independent variables, which affect energy use, are not excessively difficult or expensive to monitor.

e) Sub-meters already exist to isolate energy use of systems.

f) Meters added at the measurement boundary can be used for other purposes such as operational feedback or tenant billing.

g) Measurement of parameters is less costly than Option D simulations or Option C non-routine adjustments.

h) Long term testing is not warranted.

i) There is no need to directly reconcile savings reports with changes in payments to energy suppliers.

6.2.2 Retrofit isolation: key parameter measurement

Under Option A, Retrofit Isolation: Key Parameter Measurement, energy quantities in the following equation:

Savings = (Baseline Energy – Reporting Period Energy) ± Routine Adjustments ± Non-Routine Adjustments

This can be derived from a computation using a combination of measurements of some parameters and estimates of the others. Such estimates should only be used where it can be shown that the combined uncertainty from all such estimates will not significantly affect the overall reported savings. Decide which parameters to measure and which to estimate by considering each parameter's contribution to the overall uncertainty of the reported savings. The estimated values and analysis of their significance should be included in the M&V Plan. Estimates may be based on historical data such as recorded operating hours from the baseline, equipment manufacturer's published ratings, laboratory tests, or typical weather data.

If a parameter, such as hours of use is known to be constant and not expected to be impacted by the ECM, then its measurement in the reporting period is sufficient. The reporting period measurement of such constant parameter can also be considered a measurement of its baseline value.

Wherever a parameter, known to vary independently, is not measured in the facility during both the baseline and reporting periods, the parameter should be treated as an estimate.

Engineering calculations or mathematical modelling may be used to assess the significance of the errors in estimating any parameter in the reported savings. The combined effect of estimations should be assessed before determining whether sufficient measurement is in place.

The selection of which factor(s) to measure may also be considered relative to the objectives of the project or the duties of a contractor undertaking some ECM-performance risk. Where a factor is significant to assessing performance, it should be measured. Other factors beyond the contractor's control can be estimated.

If a savings computation involves subtracting a measured parameter from an estimated parameter, the result is an estimate.

When planning an Option A procedure, consider both the amount of variation in baseline energy and the ECMs energy impact before establishing which parameter(s) to measure. The following three examples show the range of scenarios that may arise.

a) ECM reduces a constant load without changing its operating hours.

b) ECM reduces operating hours while load is unchanged.

c) ECM reduces both equipment load and operating hours.

Generally, conditions of variable load or variable operating hours require more rigorous measurement and computations.

6.2.3 Calculations

However under Option A, there may be no need for adjustments, routine or non-routine, depending upon the location of the measurement boundary, the nature of any estimated values, the length of the reporting period, or the amount of time between baseline measurements and reporting-period measurements.

Similarly, baseline or reporting-period energy measurements involve measurement of only one parameter under Option A, and estimation of the other. Therefore the proper equation becomes:

Option A Savings = Estimated Value x (Baseline-Period, measured parameter – Reporting-period, measured parameter)

6.2.4 Installation verification

Since some values may be estimated under Option A, great care is needed to review the engineering design and installation to ensure that the estimates are realistic, achievable, and based on equipment that should truly produce savings as intended.

At defined intervals during the reporting period, the installation should be re-inspected to verify continued existence of the equipment and its proper operation and maintenance. Such re-inspections will ensure continuation of the potential to generate predicted savings and validate estimated parameters. The frequency of these re-inspections is determined by the likelihood of performance changes. Such likelihood can be established through initial frequent inspections to establish the stability of equipment existence and performance.

6.2.5 Cost

Savings determinations under Option A can be less costly than under other options, since the cost of estimating a parameter is often significantly less than the cost of measurement. However in some situations where estimation is the only possible route, a good estimate may be costlier than if direct measurement were possible. Cost planning for Option A should consider all elements: analysis, estimation, meter installation, and the ongoing cost to read and record data.

6.2.6 Best applications

Option A is best applied where:

a) estimation of non-key parameters may avoid possibly difficult non-routine adjustments when future changes happen within the measurement boundary;

b) uncertainty created by estimations is acceptable;

c) continued effectiveness of the ECM can be assessed by simple routine re-testing of key parameters;

d) estimation of some parameters is less costly than measurement of them in Option B or simulation in Option D;

e) key parameter(s) used to judge a project's or contractor's performance in computing savings can be readily identified.

6.3 Option B: Retrofit-isolation all parameter measurement

6.3.1 General

Option B Retrofit Isolation all parameter measurement, requires measurement of energy quantities, or parameters needed to compute energy for the equation below.

Savings = (Baseline-Period Use or Demand - Reporting-Period Use or Demand) ± Adjustments

The savings created by most types of ECMs can be determined with Option B. However, the degree of difficulty and costs increase as metering complexity increases. Option B methods will generally be more difficult and costly than those of Option A. However, Option B will produce more certain results where load or savings patterns are variable. These additional costs may be justifiable if a contractor is responsible for factors affecting energy savings.

6.3.2 Calculations

Savings = (Baseline-Period Use or Demand - Reporting-Period Use or Demand) ± Adjustments

is used in IPMVP adherent computations. However under Option B, there may be no need for adjustments, routine or non-routine, depending upon the location of the measurement boundary, the length of the reporting period, or the amount of time between base line and reporting period measurements. Therefore, for Option B, may simplify down to:

Option B Savings = Baseline Energy - Reporting-Period Energy

6.3.3 Measurement issues

Retrofit isolation usually requires the addition of special meters, on either a short term or permanent basis. These meters may be installed during an energy audit to help characterize energy use before design of the ECM. Alternatively, meters may be installed to measure baseline performance for an M&V Plan.

Follow good measurement practices to enable calculation of energy savings with reasonable accuracy and repeatability. Measurement practices are continually evolving as metering equipment improves. Therefore, use the latest measurement practices to support the savings.

6.3.3.1 Electricity measurements

To measure electricity accurately, measure the voltage, amperage and power factor, or true rms wattage with a single instrument. However, measurement of amperage and voltage alone can adequately define wattage in purely resistive loads, such as incandescent lamps and resistance heaters without blower motors. When measuring power, make sure that a resistive load's electrical wave-form is not distorted by other devices in the facility.

Measure electric demand at the same time that the power company determines the peak demand for its billing. This measurement usually requires continuous recording of the demand at the sub-meter. From this record, the sub-meter's demand can be read for the time when the power company reports that the peak demand occurred on its meter. The power company may reveal the time of peak demand either on its invoices or by special report.

Electric-demand measurement methods vary amongst utilities. The method of measuring electric demand on a sub-meter should replicate the method the power company uses for the relevant billing meter.

However, care should be taken to ensure that the facility does not contain unusual combinations of equipment that generate high one minute peak loads which may show up differently in a moving interval than in a fixed interval. After processing the data into power company intervals, convert it to hourly data for archiving and further analysis.

6.3.3.2 Calibration

Meters should be calibrated as recommended by the equipment manufacturer, and following procedures of recognized measurement authorities. Primary standards and no less than third-order-standard traceable calibration equipment should be utilized wherever possible. Sensors and metering equipment should be selected based in part on the ease of calibration and the ability to hold calibration. An attractive solution is the selection of equipment that is self-calibrating.

6.3.4 Best applications

Option B is best applied where:

a) meters added for isolation purposes will be used for other purposes such as operational feedback or tenant billing;

b) measurement of the parameters is less costly than simulation in Option D;

c) savings or operations within the measurement boundary are variable.

6.4 Option C: Whole-Facility

6.4.1 General

Option C: Whole Facility, involves use of utility meters, whole-facility meters, or sub-meters to assess the energy performance of a total facility. The measurement boundary encompasses either the whole facility or a major section. This option determines the collective savings of ECMs applied to the part of the facility monitored by the energy meter. Also, since whole-facility meters are used, savings reported under Option C include the positive or negative effects of any non-ECM changes made in the facility.

Option C is intended for projects where expected savings are large compared to the random or unexplained energy variations which occur at the whole-facility level. If savings are large compared to the unexplained variations in the baseline-energy data, then identifying savings will be easy. Also the longer the period of savings analysis after ECM installation, the less significant is the impact of short-term unexplained variations. Typically savings should exceed 10% of the baseline energy if you expect to confidently discriminate the savings from the baseline data when the reporting period is shorter than two years.

NOTE RMS (root mean squared) values can be reported by solid state digital instruments properly account for the net power wave distortions exist in alternating current circuits.

Identifying facility changes that will require non-routine adjustments is the primary challenge associated with Option C, particularly when savings are monitored for long periods. Therefore, periodic inspections should be performed of all equipment and operations in the facility during the reporting period. These inspections identify changes in the static factors from baseline conditions. Such inspections may be part of regular monitoring to ensure that the intended operating methods are still being followed.

6.4.2 Energy data issues

Where utility supply is only measured at a central point in a group of facilities, sub-meters are needed at each facility or group of facilities for which individual performance is assessed.

Several meters may be used to measure the flow of one energy type into a facility. If a meter supplies energy to a system that interacts with other energy systems, directly or indirectly, this meter's data should be included in the whole-facility savings determination.

Meters serving non-interacting energy flows, for which savings are not to be determined, can be ignored. Determine savings separately for each meter or sub-meter serving a facility so that performance changes can be assessed for separately metered parts of the facility. However, where a meter measures only a small fraction of one energy type's total use, it may be totaled with the larger meter(s) to reduce data-management tasks. When electrical meters are combined this way, it should be recognized that small consumption meters often do not have demand data associated with them so that the totalized consumption data will no longer provide meaningful load factor information.

If several different meters are read on separate days, then each meter having a unique billing period should be separately analyzed. The resultant savings can be combined after analysis of each individual meter, if the dates are reported.

If any of the energy data are missing from the reporting period, a reporting-period mathematical model can be created to fill in missing data. However the reported savings for the missing period should identify these savings as "missing data."

6.4.3 Energy invoice issues

Energy data for Option C are often derived from utility meters, either through direct reading of the meter, or from utility invoices. Where utility bills are the source of data, it should be recognized that a utility's need for regular meter reading is not usually as great as the needs of M&V. Utility bills sometimes contain estimated data, especially for small accounts. Sometimes it cannot be determined from the bill itself whether the data came from an estimate or an actual meter reading. Unreported estimated meter readings create unknown errors for estimated month(s) and also for the subsequent month of the actual meter reading. However the first invoice with an actual reading after one or more estimates will correct the previous errors in energy quantities. Savings reports should note when estimates are part of the utility data.

When an electrical utility estimates a meter reading, no valid data exist for the electrical demand of that period.

Energy may be supplied indirectly to a facility, through on-site storage facilities, such as for oil, propane or coal. In these situations, the energy supplier's shipment invoices do not represent the facility's actual consumption during the period between shipments. Ideally a meter downstream of the storage facility measures energy use. However where there is no downstream meter, inventory-level adjustments for each invoice period should supplement the invoices.

6.4.4 Independent variables

Common independent variables are weather, production volume and occupancy. Weather has many dimensions, but for whole-facility analysis, weather is often just outdoor dry-bulb temperature. Production has many dimensions, depending upon the nature of the industrial process. Production is typically expressed in mass units or volumetric units of each product. Occupancy is defined in many ways, such as hotel-room occupancy, office-building occupancy hours, occupied days (weekdays/weekends), or restaurant-meal sales.

Mathematical modeling can assess independent variables if they are cyclical. Regression analysis and other forms of mathematical modeling can determine the number of independent variables to consider in the baseline data. Parameters, which have a significant effect on the baseline energy use, should be included in the routine adjustments when determining savings using one of the following equations:

Savings = (Baseline Energy – Reporting Period Energy) ± Routine Adjustments ± Non-Routine Adjustments

Avoided Energy Use (or Savings) = Adjusted-Baseline Energy – Reporting-Period Energy ± Non-Routine Adjustments of Baseline Energy to Reporting-Period Conditions

Normalized Savings = (Baseline Energy ± Routine Adjustments to fixed conditions ± Non-Routine Adjustments to fixed conditions) - (Reporting Period Energy ± Routine Adjustments to fixed conditions ± Non-Routine Adjustments to fixed conditions)

Independent variables should be measured and recorded at the same time as the energy data.

6.4.5 Calculations and mathematical models

For Option C, the routine adjustments term, in the following equation, is calculated by developing a valid mathematical model of each meter's energy-use pattern:

Savings = (Baseline Energy – Reporting Period Energy) ± Routine Adjustments ± Non-Routine Adjustments

A model may be as simple as an ordered list of twelve measured monthly energy quantities without any adjustments. However a model often includes factors derived from regression analysis, which correlates energy to one or more independent variables such as outdoor temperature, degree days, metering period length, production, occupancy, or operating mode. Models can also include a different set of regression parameters for each range of conditions, such as summer or winter in buildings with seasonal energy use variations.

Option C should use complete years (twelve, twenty-four, or thirty-six months) of continuous data, during the baseline period, and continuous data during the reporting periods (Fels 1986). Models, which use other numbers of months, (nine, ten, thirteen, or eighteen months) can create statistical bias by under or over-representing normal modes of operation.

Meter data can be hourly, daily or monthly whole-facility data. Hourly data should be combined into daily data to limit the number of independent variables required to produce a reasonable baseline model, without significantly increasing the uncertainty in computed savings (Katipamula 1996, Kissock et al. 1992). Variation in the daily data often results from the weekly cycle of most facilities.

Many mathematical models are appropriate for Option C. To select the one most suited to the application, consider statistical-evaluation indices, such as R2 and t, or published statistical literature can help demonstrate the statistical validity of the selected model.

6.4.6 Metering

Whole-facility energy measurements can use the utiltity's meters. Utility-meter data are considered 100% accurate for determining savings because the data defines the payment for energy. Utility-meter data are subject to local commercial accuracy regulations for sale of energy commodities.

The energy supplier's meter(s) may be equipped or modified to provide an electical pulse output that can be recorded by the facility's monitoring equipment. The energy-per-pulse constant of the pulse transmitter should be calibrated against a known reference such as similar data recorded by the utility meter.

Separate meters installed by the facility owner can measure whole-facility energy. The accuracy of these meters should be considered in the M&V Plan, together with a way of comparing its readings with the utility meter readings.

6.4.7 Cost

Option C's cost depends on the source of the energy data, and the difficulty of tracking static factors within the measurement boundary to enable non-routine adjustments during the reporting period. The utility meter or an existing sub-meter works well if the meter's data are properly recorded. This choice requires no extra metering cost.

The cost of tracking changes in static factors depends on the facility's size, the likelihood of static-factor change, the difficulty of detecting changes, and the surveillance procedures already in place.

6.4.8 Best applications

Option C is best applied where:

a) energy performance of the whole facility will be assessed, not just the ECMs;

b) there are many types of ECMs in one facility;

c) ECMs involve activities whose individual energy use is difficult to separately measure;

d) savings are large compared to the variance in the baseline data, during the reporting period;.

e) retrofit-isolation techniques (Option A or B) are excessively complex;

f) significant future changes to the facility are not expected during the reporting period;

g) system of tracking static factors can be established to enable possible future non-routine adjustment;

h) reasonable correlations can be found between energy use and other independent variables.

6.5 Options D: Calibrated Simulation

6.5.1 General

Option D: Calibrated Simulation, involves the use of computer simulation software to predict facility energy for one or both of the terms in the savings equation. A simulation model must be "calibrated" so that it predicts an energy pattern that approximately matches actual metered data.

Option D may be used to assess the performance of ECMs in a facility, akin to Option C. However, the option D simulation tool allows you to also estimate the savings attributable to each ECM within a multiple ECM project.

Option D may also be used to assess just the performance of individual systems within a facility, akin to options A and B. In this case, the system's energy use must be isolated from that of the rest of the facility by appropriate meters.

Option D is useful where:

a) baseline energy data do not exist or are unavailable. Such a situation may arise for a:

- new construction project,
- facility expansion needing to be assessed separately from the rest of the facility, or
- centrally metered campus of facilities where no individual facility meter exists in the baseline period, but where individual meters will be available after ECM installation.

b) reporting period energy data are unavailable or obscured by factors that are difficult to quantify. Sometimes it is too difficult to predict how future facility changes might affect energy use. Industrial process changes or new equipment often make the computation of non-routine adjustments so inaccurate the Options A, B or C would create excessive error in the savings determination.

c) it is desired to determine the savings associated with individual ECMs, but measurements with Options A or B are too difficult or costly.

d) if the reporting period energy is predicted by the simulation software, the determined savings persist only if the simulated operating methods continue. Periodic inspections will identify changes from baseline conditions and modelled equipment performance. Simulation runs should be adjusted accordingly.

e) option D is the primary M&V approach for assessing energy efficiency inclusion in new facility designs. The IPMVP Volume III Part I, titled *Concepts and Options for Determining Savings in New Construction*, provides guidance on a variety of M&V techniques applicable to new buildings.

f) accurate computer modelling and calibration to measured energy data are the major challenges associated with Option D. To control the costs of this method while maintaining reasonable accuracy, the following points should be considered when using Option D:

   i. Simulation analysis should be conducted by trained personnel who are experience with both the software and the calibration techniques.

   ii. Input data should represent the best available information including as much as possible of available actual performance data from key components in the facility.

   iii. The simulation inputs need to be adjusted so its results match both the demand and consumption data from monthly utility bills, within acceptable tolerances (i.e. calibrated). Close agreement between predicted and actual annual total energy is usually insufficient demonstration that the simulation adequately predicts the energy behaviour of the facility.

   iv. Option D requires careful documentation. Simulation printouts, survey data and the metering or monitoring data used to define input values and calibrate the simulation model should be kept in paper and electronic files. The version number should be declared of publicly available software, so that another person can review the computations.

   v. For new construction projects, modelling efforts can be streamlined by retaining the building energy modeller that created the "as-designed" model to create the calibrated, "as-built" and adjusted baseline models.

Building types which are not easily simulated include those with:

- o large atriums;

- significant fraction of the space underground or ground coupled;
- unusual exterior shapes;
- complex shading configurations; or
- a large number of distinct zones of temperature control.

Some building ECMs cannot be simulated without great difficulty, such as:

1. addition of radiant barriers in attics; and
2. some complex HVAC system changes

6.5.2 Types of simulation programs

Whole- building-simulation programs usually use hourly calculation techniques. However simplified HVAC system models may also be used if the building's heat losses, heat gains, internal loads, and HVAC systems are simple. Other types of special-purpose programs may be used to simulate energy use and operation of devices or industrial processes.

Any software used must be well documented and well understood by the user. Due to the wide variety of available methods, it is prudent to receive acceptance by the owner or project authority of the proposed modelling program before commencing analysis.

6.5.3 Calibration

Savings determined with Option D are based on one or more complex estimates of energy use. The accuracy of the savings depends on how well the simulation models actual equipment performance, and how well calibrated it is to metered energy performance.

Calibration is achieved by verifying that the simulation model reasonably predicts the energy patterns of the facility by comparing model results to a set of calibration data. These calibration data include measured energy data, independent variables and static factors.

Calibration of building simulations is usually done with twelve monthly utility bills. These bills should be from a period of stable operation. In a new building, it may take a number of months before full occupancy and before the staff learns the best ways to operate the facility. The calibration data should be documented in the M&V Plan along with a description of its sources.

Detailed operating data from the facility help to develop the calibration data. These data might include operating characteristics, occupancy, weather, loads and equipment efficiency. Some variables may be measured for short intervals (day, week or month) or extracted from existing operating logs. The accuracy of meters should be verified for critical measurements. If resources permit, building ventilation and infiltration should be measured because these quantities often vary widely from expectations. One-time measurements will improve simulation accuracy without much additional cost. On/off tests can measure lighting, receptacle loads and motor control centers. These tests can be performed over a weekend using a data logger or building automation system to record whole-facility energy use, usually at one-minute intervals. Sometimes, inexpensive portable loggers, which are synchronized to a common time, are also effective for short-term measurement.

Following collection of as much calibration data as possible, the steps in calibrating the simulation are as listed below.

1) Assume other necessary input parameters, and document them.
2) Whenever possible, gather actual weather data from the calibration period, especially if weather conditions varied significantly from standard-year weather data used in the basic simulations. However, obtaining and preparing actual weather data for use with a simulation may be time-consuming and expensive. If developing an actual weather data file is too difficult, then adjust an average weather file to resemble actual weather data using valid statistical methods.
3) Run the simulation and verify that it predicts operating parameters such as temperature and humidity.
4) Compare the simulated energy results with the metered energy data from the calibration period, on an hourly or monthly basis.
5) Evaluate patterns in the differences between simulation results and calibration data. Bar charts, monthly per cent difference time-series graphs, and monthly x-y scatter plots help to identify the error patterns. The calibration accuracy should be established in the M&V Plan to accommodate the M&V budget.

6) Revise input data in step 1 and repeat steps 3 and 4 to bring predicted results within the calibration specifications in 5, above. Collect more actual operating data from the facility to meet the calibration specification if necessary.

7) The creation and calibration of a simulation is time consuming. Using monthly rather than hourly energy data helps to limit the effort needed for calibration. However if Option D will be used to determine savings at the ECM level, calibration of major end-uses, systems, and/or equipment impacted by the ECMs is recommended.

6.5.4 Calculations

Savings can be determined using calibrated simulation results representing the baseline energy or the reporting-period energy. For projects with a physical baseline, the two calibrated models include one with the ECMs and one without them. For projects with a hypothetical baseline, calibrated models may include the hypothetical baseline and the as-built (reporting period) conditions, but measured data will only be available for calibration under as-built conditions. In either case, both models and measured energy data must be under the same set of operating conditions.

Savings with Option D can be estimated using two forms of the savings equation. Both forms presume that the calibration 'error' equally affects both baseline and reporting period models. The same savings will be determined from the two equations for any given set of data and simulations.

Savings= Baseline Energy from the calibrated model [hypothetical or with ECMs] – Reporting Period Energy from the calibrate model [with ECMs]

One of the model-derived energy terms in the equation above may be replaced by the actual measured energy. However, the calculation must be adjusted for the calibration error for each month in the calibration period, using the equation below.

Savings = Baseline energy from the calibrated model [hypothetical or with ECMs] – Actual calibration period energy ± calibration error in the corresponding calibration reading

The equation below for Savings may be more easily understood by non-technical persons, since the final savings uses actual metered data rather than only the results of simulation models.

Savings = (Baseline-Period Use or Demand - Reporting-Period Use or Demand) ± Adjustments

6.5.5 On-going savings reporting

If multi-year performance evaluation is required, Option D may be used for the first year after the ECMs are installed. In later years, Option C may be less costly than Option D if you use as the baseline the meter data from the first year of steady operation after installation. Then Option C is used to determine whether energy use changes from the first year of operation after the ECM was installed. In this situation, the first year of steady operation's energy use would be used to:

a) calibrate an Option D simulation model, and

b) establish an Option C baseline for measuring additional savings (or losses) in the second year and beyond.

6.5.6 Best applications

Option D is usually used where no other option is feasible. It is best where:

a) either baseline energy data or reporting period energy data but not both, are unavailable or unreliable;

b) there are too many ECMs to assess using Options A or B;

c) ECMs involve diffuse activities, which cannot easily be isolated from the rest of the facility, such as operator training or wall and window upgrades;

d) performance of each ECM will be estimated individually within a multiple ECM project, but the costs of Options A or B are excessive;

e) interactions between ECMs or ECM interactive effects are complex, making the isolation techniques of Options A and B impractical;

f) upcoming significant changes to the facility are expected during the reporting period, with no accounting for the energy use or impact;

g) experienced energy simulation professional is able to gather appropriate input data to calibrate the simulation model;

h) facility and ECMs can be modelled by well-documented simulation software;

i) simulation software predicts metered calibration data with acceptable accuracy;

j) twelve months of performance is measured, immediately following installation and commissioning of the energy management program.

7 M&V plan

7.1 General

A key component of an adherent M&V project is the documentation of a well-considered and customized M&V plan. The following sections describe the essential requirements of an M&V Plan.

7.2 ECM intent

Describe the ECM, its intended result, and the operational verification procedures that will be used to verify successful implementation of each ECM. Identify any planned changes to conditions of the baseline, such as unoccupied building temperature settings.

7.3 Selected IPMVP option and measurement boundary

Specify which IPMVP option will be used to determine savings. Identify the measurement boundary of the savings determination. The boundary may be as narrow as the flow of energy through a pipe or wire, or as broad as the total energy use of one many facilities. Describe the nature of any interactive effects beyond the measurement boundary together with their possible effects.

7.4 Baseline: period, energy and conditions

Document the facility's baseline conditions and energy data, within the measurement boundary.
This baseline documentation should include:

a) identification of the baseline period;

b) baseline energy consumption and demand data;

c) independent variable data coinciding with the energy data (e.g.. production data, ambient temperature);

d) static factors coinciding with the energy data;

  1) occupancy type, density and periods;

  2) operating conditions for each baseline operating period and season, other than the independent variables.

  3) description of any baseline conditions that fall short of required conditions;

e) details of adjustments that are necessary to the baseline energy data to reflect the energy management programme's expected improvement from baseline conditions;

f) size, type and insulation of any relevant building envelope elements such as walls, roofs, doors, windows;

g) equipment inventory;

h) equipment operating practices;

i) any design, install, calibrate, and commission and any special measurement equipment that is needed under the plan;

j) significant equipment problems or outages during the baseline period;

The baseline documentation typically requires well-documented short term metering activities. The extent of this information is determined by the measurement boundary chosen or the scope of the savings determination. If the whole-facility M&V methods are employed, all facility equipment and conditions should be documented.

7.5 Reporting period

Identify the reporting period, which may be as short as an instantaneous measurement during commission of an ECM, or as long as the time required to recover the investment cost of the ECM.

7.6 Basis for adjustment

Declare the set of conditions to which energy measurements will be adjusted. The conditions may be those of the reporting period or some other set of fixed conditions. The conditions for the basis for adjustment determine whether savings are reported as avoided energy or as normalized savings.

7.7 Analysis procedure

Specify the exact data analysis procedures, algorithms and assumptions to be used in each savings report. For each mathematical model used, report the terms, and range of independent variables over which it is valid.

7.8 Energy prices

Specify the energy prices that will be used to value the savings, and whether and how savings will be adjusted if energy prices change during the ECM or in the future.

7.9 Meter specifications

Specify the metering points and period if metering is not continuous. For non-utility meters, specify:

- meter characteristics;
- meter reading and witnessing protocol;
- meter commissioning or calibration procedure;
- routine calibration process;
- method of dealing with lost data and data transfer.

7.10 Monitoring responsibilities

Assign responsibilities for reporting and recording during the reporting period:

a) energy data;

b) independent variables;

c) static factors within the measurement boundary.

7.11 Expected accuracy

Evaluate the expected accuracy associated with the measurement, data capture, sampling and data analysis. This assessment should include qualitative and any feasible quantitative measures of the level of uncertainty in the measurements and adjustments to be used in the planned savings report.

7.12 Budget

Define the budget and the resources required for the savings determination, both initial setup costs and on-going costs throughout the reporting period.

7.13 Report format

Specify how results will be reported and documented.

7.14 Quality assurance

Specify quality-assurance procedures that will be used for savings reports and ay interim steps in preparing reports.

7.15 Additional M&V plan requirements for option A

7.15.1 Justification of estimates

Report the values to be used for estimated values. Explain the source of these estimated values. Show the overall significance of these estimates to the total expected savings by reporting the range of possible savings associated with the range of plausible values of the estimated parameters.

7.15.2 Periodic inspections

Define the periodic inspections that will be performed in the reporting period to verify that equipment is still in place an operating as assumed when determining the estimated values.

7.16 Additional M&V plan requirements for option D

7.16.1 Software name

Report the name and the version number of the simulation software to be used.

7.16.2 Input/output data

Provide a paper and electronic copy of the input files, output files and weather files used for the simulation.

7.16.3 Measured data

Describe the process of obtaining any measured data. Record which input parameters were measured and which input parameters were estimated.

7.16.4 Calibration

Report the energy and operating data used for calibration. Report the accuracy with which the simulation results match the calibration energy data.

7.16.5 Future changes

Where possible, define the method for making relevant non-routine adjustments.

8 M&V reports

M&V reports are prepared as defined by the M&V plan. The report will include as a minimum the following:

a) the needs of the user of the planned M&V report(s);

b) choice of method or technique;

  — if the user is focused on the overall cost control, the whole facility methods may be the most suited,

  — if the user is focused on particular ECMs, retrofit isolation techniques may be most suited,

c) observed data of the reporting period;

  1) the measurement period start and end point in time,

  2) the energy data,

  3) the values of the independent variables,

d) description and justification for any corrections made to observed data;

e) for Option A, the agreed estimated values;

f) energy price schedule used;

g) details of any baseline non-routine adjustments;

h) computed savings in energy;

i) computed savings in monetary units;

j) input from the review of the report with the facility operating staff.

9 Adherence with IPMVP

IPMVP is a framework of definitions and methods for properly assessing savings in energy or water use or demand. The IPMVP guides users in developing M&V Plans for specific projects. IPMVP is written to allow maximum flexibility in creating M&V Plans, while adhering to the principles of accuracy, completeness, conservativeness, consistency, relevance and transparency (see Principles).

Users claiming adherence with IPMVP must:

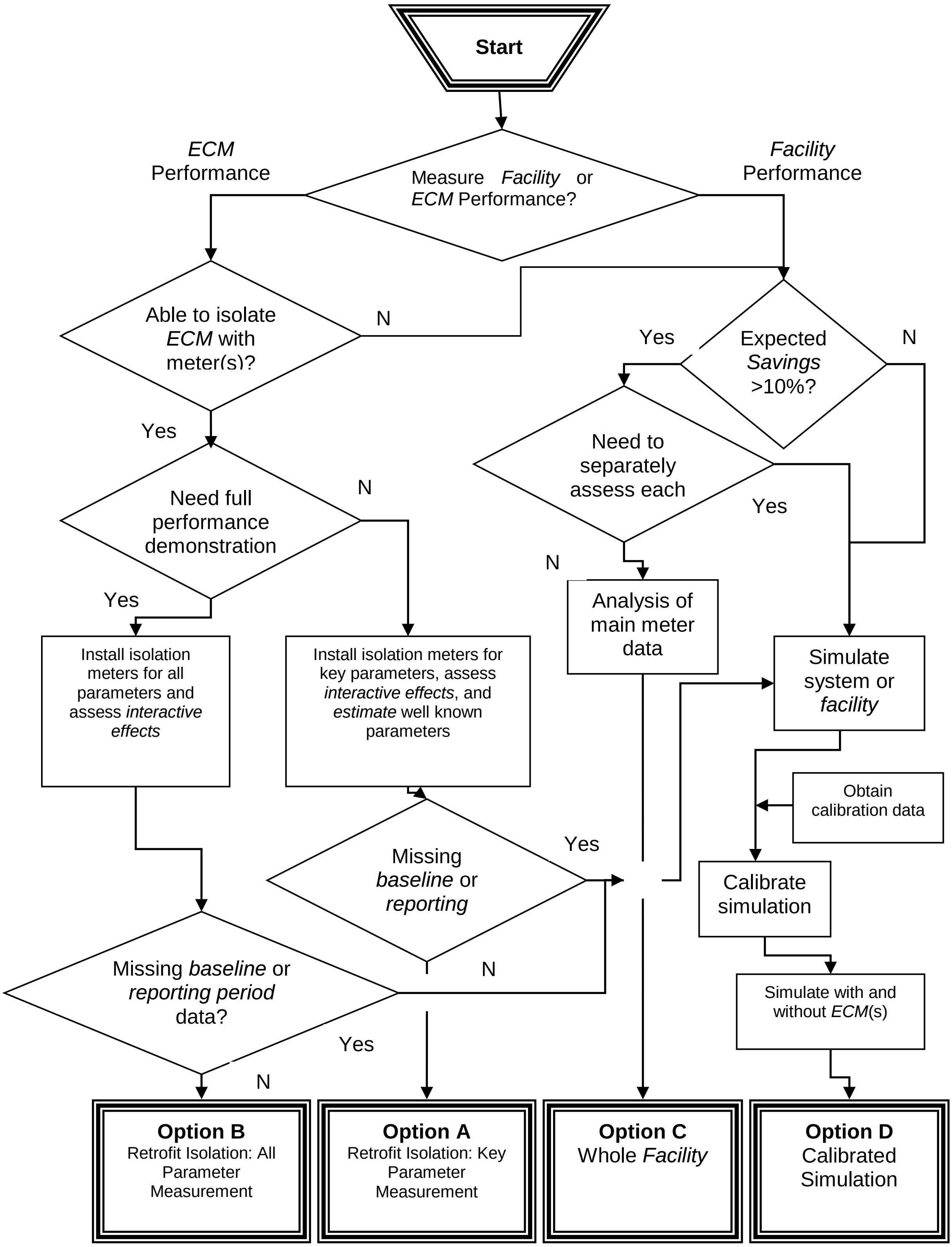
1. Identify the person responsible for approving the site-specific M&V Plan, and for making sure that the M&V Plan is followed for the duration of the reporting period.
2. Develop a complete M&V Plan which:
   - clearly states the date of publication or the version number of the IPMVP edition and Volume being followed,
   - uses terminology consistent with the definitions in the version of IPMVP cited or source for terminology,
   - includes all information mentioned in the *M&V Plan* chapter (Chapter 5 of the present edition),
   - is approved by all parties interested in adherence with IPMVP, and
   - is consistent with the Principles of *M&V*.
3. Follow the approved IPMVP adherent M&V Plan.
4. Prepare M&V reports containing the information according to section 9.

Users wishing to specify the use of IPMVP in an energy performance contract or emission trade may use phrases such as, “The determination of actual energy and monetary savings will follow current best practice, as defined in IPMVP Volume I".

Specification may go further to include “The M&V Plan shall adhere to IPMVP and be approved by……” and may also, if known at the time of contract approval, add, “following IPMVP Option ….”

Annex A
(informative)

Option Selection Process Diagram



Annex B
(informative)

ECM Project Characteristics

ECM Project Characteristic	Suggested Option			
	A	**B**	**C**	**D**
Need to assess *ECM*s individually	X	X		X
Need to assess only total facility performance			X	X
Expected *savings* less than 10% of utility meter	X	X		X
Significance of some *energy* driving variables is unclear		X	X	X
Interactive effects of ECM are signficant or unmeasurable			X	X
Many future changes expected within *measurement boundary*	X			X
Long term performance assessment needed	X		X	
Baseline data not available				X
Non-technical persons must understand reports	X	X	X	
Metering skill available	X	X		
Computer simulation skill available				X
Experience reading utility bills and performing regression analysis available			X	

EVO Would Like to Thank its Organizational Subscribers:

Primary:

BC Hydro
Services Industriels de Genève

Senior:

EDF Electricité de France
Pacific Gas& Electric
Southern California Edison
Schneider- Electric

Large Government:

Ontario Power Authority
Bonneville Power Administration

Small Government:

ADENE – Agência para a Energia(Portuguese Energy Agency)

Educational:

Université de Genève

Associate Annex 1:

Navigant Consulting Inc.

Quantum Energy Services & Technologies, Inc. (QuEST)

EEVS – Energy Efficiency Verification Specialists

HEP-ESCO d.o.o.

Non Profit Non Annex 1:

Taiwan Green Productivity Foundation (TGPF)