IPMVP CORE CONCEPTS

WORKING DOCUMENT

FIVE-YEAR STATUTORY PROTOCOL REVIEW

REFERENCE COPY FOR PUBLIC COMMENTS

Scope

The Efficiency Valuation Organization (EVO) publishes the International Performance Measurement and Verification Protocol (IPMVP) and related documents shown below to help ensure the accurate assessment of investment in energy and water efficiency, demand management and renewable energy projects around the world. In addition to the Core Concepts, several Application Guides pictured below have been updated as well. All of these resources and more can be found on the EVO website.

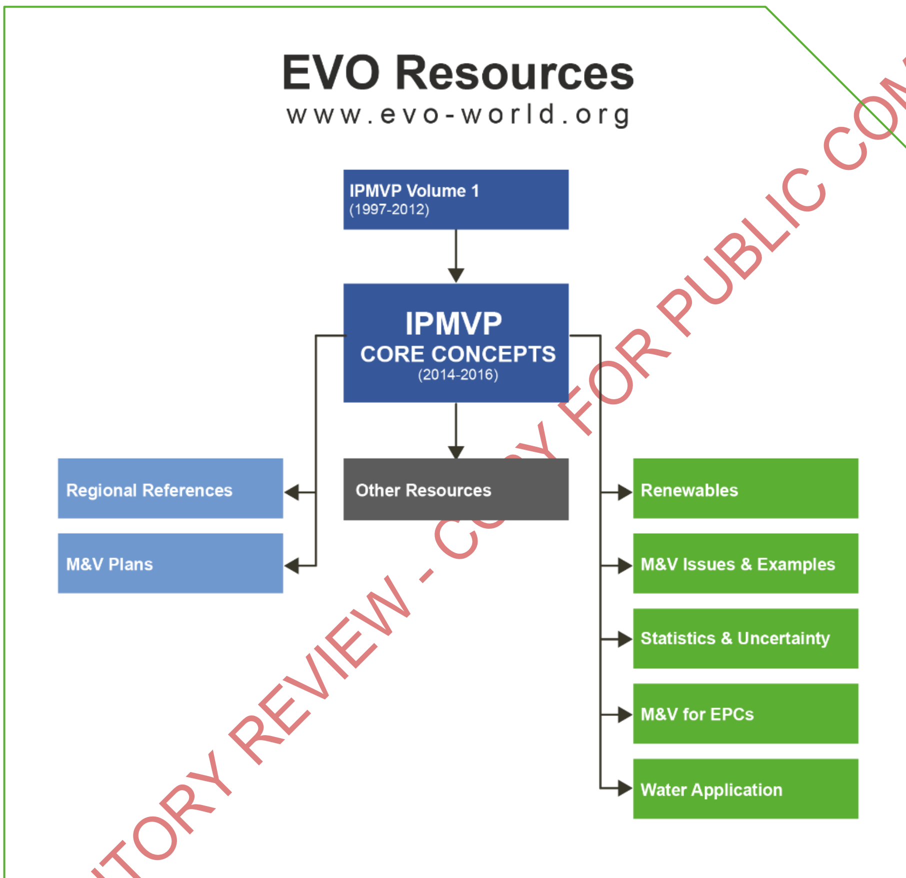

Figure 1. Chart of the IPMVP Core Concepts and Application Guides

1. Normative References

The following referenced publications are closely related to the IPMVP and can be useful in applying the concepts presented in this document. It is the intent of the IPMVP that other industry publications be used in conjunction with this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document, including any amendment applies.

- M&V Guidelines: Measurement & Verification for Performance Based Contracts, Version 4.0, U.S. Department of Energy Federal Energy Management Program (FEMP)
- ASHRAE Guideline 14: Measurement of Energy and Demand Savings
- Italian Standard on Energy Service Companies UNI/CEI 11352
- UNE-EN 15900:2010 Energy Efficiency Services Directive 2006/32/EC
- U.K. Electricity Demand Reduction Scheme Pilot Phase II - Measurement and Verification Manual
- U.K. Department of Energy and Climate Change - Guide to Energy Performance Contracting Best Practices
- Transparence European Code of Conduct for Energy Performance Contracting

2. Terms & Definitions

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

> ***Note:*** *To maintain clarity in the text, although explicit references to energy are made throughout the document, the methods described to measure and verify energy savings apply equally to water measures and their savings.*

Adjusted Baseline Energy

The Baseline Period Energy Consumption modified as part of Routine and Non-Routine Adjustments to account for changes in the Reporting Period.

Avoided Energy Consumption and Demand

Reduction in *Energy Consumption*, demand or cost that occurred in the *Reporting Period*, relative to the *Baseline Period*, as adjusted for the Reporting Period conditions. Avoided *Energy Consumption* is determined by adjusting the *Baseline Period Energy* to the Reporting Period conditions by using *Routine Adjustments* and *Non-Routine Adjustments*.

Baseline

Referring to the systems, time period, energy use, or conditions that provide a reference to which later performance of an *Energy Conservation Measure (ECM) or measures* can be compared.

Baseline Period

Defined period of time chosen to represent the operation of the facility or system before the implementation of an *Energy Conservation Measure*.

Baseline Period Energy

Energy Consumption and demand occurring during the *Baseline Period* without adjustments.

Building Automation System (BAS)

A measure using the buildings *control system* to trend data which will be used to assess the operational and energy performance of conservation measures. The results are then used to inform the verified saving calculations.

Demand

A measure of the rate at which work is done or energy is converted.

Energy Conservation Measure (ECM)

Action or set of actions designed to improve efficiency or conserve energy or water or manage demand.

Energy Consumption

Quantity of energy applied to any load.

Energy Performance Contract

Agreement between two or more parties where payment is based on achieving specified results, such as reductions in energy costs or payback of investment within a stated period.

Energy End Use

Application of energy for a specific purpose.

> **Examples:** *Ventilation, lighting, heating, cooling, transportation, industrial processes, production line.*

Estimated Value

Parameters used in saving calculations determined through methods other than conducting measurements. The methods used to estimate values may range from arbitrary assumptions to engineering estimates derived from manufacturer ratings of equipment performance. Parameter values derived from equipment performance tests or other measurements that are not made in situ are considered to be estimates for purposes of adherence with IPMVP.

Independent Variable

Parameter that is expected to change routinely and have a measurable impact on *Energy Consumption* and/or *Demand* of a system or facility.

Interactive Effect

Energy impacts created by an *Energy Conservation Measure* that cannot be measured within the *Measurement Boundary*.

Key Parameter

Critical variable identified to have a significant impact on the energy savings associated with the installation of an *Energy Conservation Measure*.

Measurement and Verification (M&V)

Process of planning, measuring, collecting and analyzing data for the purpose of verifying and reporting energy savings within an individual facility resulting from the implementation of ECMs.

Measurement Boundary

Notional boundaries drawn around equipment, systems or facilities to segregate those which are relevant to saving determination from those which are not. All *Energy Consumption* and *Demand* of equipment or systems within the boundary must be measured or estimated.

Non-Routine Adjustment

Individually engineered calculations to account for the energy effects due to changes in the *Static Factors* within the *Measurement Boundary*.

Normalized Savings

Reduction in *Energy Consumption*, *demand* or cost that occurred in the *Reporting Period*, relative to the *Baseline Period*, that are adjusted to a common set of conditions. Savings are determined by adjusting the *Baseline Period* and *Reporting Period* data to the common set of conditions using *Routine Adjustments* and *Non-routine Adjustments*. The common set of conditions may be a long-term average set of conditions, or an agreed upon set of conditions, other than the *Reporting Period*.

Operational Verification

Confirmation that *Energy Conservation Measures* are installed and operating as per the design intent and have the potential to perform and generate savings. This may involve inspections, functional performance testing, and/or data trending with analysis.

Proxy Measurement

A measured parameter substituted in place of direct measurement of an energy parameter, where a relationship between the two has been proven on site.

> **Example:** *If a relationship has been proven, via measurements, between the output signal from a variable speed drive controller and the power draw of the controlled fan, then the output signal may be used as a proxy measurement for fan motor power.*

Reporting Period

Defined period of time chosen for the purposes of verifying savings after implementation of an *Energy Conservation Measure*.

Reporting Period Energy

Energy Consumption and *Demand* occurring during the *Reporting Period* without adjustments.

Routine Adjustment

Individually engineered calculations to account for the expected change in energy consumption or demand due to changes in the *Independent Variables* within the *Measurement Boundary*.

Savings

Value, in energy units, of energy consumption, water or demand reduction determined by comparing measured energy values before and after implementation of an *Energy Conservation Measure*, making suitable *Routine or Non-Routine Adjustments* for changes in conditions.

Energy unit savings and resulting cost savings may be reported in the form of *Avoided Energy Consumption* and *Normalized Savings.*

Static Factor

Those characteristics of a facility which affect *Energy Consumption* and *Demand*, within the defined *Measurement Boundary*, that are not expected to change, and were therefore not included as independent variables. If they change, *Non-routine Adjustments* need to be calculated to account for these changes.

> **Note:** *Those characteristics may include fixed, environmental, operational and maintenance characteristics.*

3. Principles

The IPMVP key principles below provide the basis for assessing adherence to the M&V process.

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. The M&V methodology's accuracy and cost should be evaluated as part of the project development. Accuracy trade-offs should be accompanied by increased conservativeness with increased use of estimated values and judgments. Consideration of all reasonable factors that affect accuracy is a guiding principle of IPMVP.

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.

Conservative

Where judgments are made about uncertain quantities, M&V procedures should be designed to responsibly estimate savings such that they are not overstated. An assessment of a project's impact should be made to assure its energy-saving benefits are both reasonable and conservative with due consideration to the level of confidence in the estimation.

Consistent

The reporting of a project's energy performance should be consistent and comparable across:

- Different types of energy efficiency projects
- Different energy management professionals for any project
- Different periods of time for the same project
- Energy efficiency projects and new energy supply projects

> **Note:** *Consistent does not mean identical, since it is recognized that any empirically derived report involves judgments which may not be made identically by all reporters. By identifying key areas of judgment, IPMVP helps to avoid inconsistencies arising from lack of consideration of important dimensions.*

Relevant

The determination of savings should be based on current measurements and information pertaining to the facility where the project occurs. This determination of saving effort must measure the performance parameters that are of concern, or that are least well known, while other less critical or more predictable parameters may use estimated values.

Transparent

All M&V activities should be clearly documented and fully disclosed. Full disclosure should include presentation of all of the elements of an M&V Plan and saving reports. Data and information collected, data preparation techniques, algorithms, spreadsheets, software, assumptions used and analysis should follow industry standard practices as closely as possible, be well formatted and documented – such that any involved party or outside quality assurance reviewer can understand how the data and analysis conformed to the M&V Plan and savings reporting procedures.

4. IPMVP Framework

Energy, water or demand savings cannot be directly measured, because savings represent the absence of energy/water consumption or demand. Instead, savings are determined by comparing measured consumption or demand before and after implementation of a program, making suitable adjustments for changes in conditions. The comparison of before and after energy consumption or demand should be made on a consistent basis, using the following general M&V equation:

Savings = (Baseline Period Energy
– Reporting Period Energy)
± Adjustments **(Eq. 1)**

Good practice requires that M&V is well integrated into the process of identifying, developing, procuring, installing and operating 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 as part of good M&V practice. This section describes such key elements of IPMVP's framework.

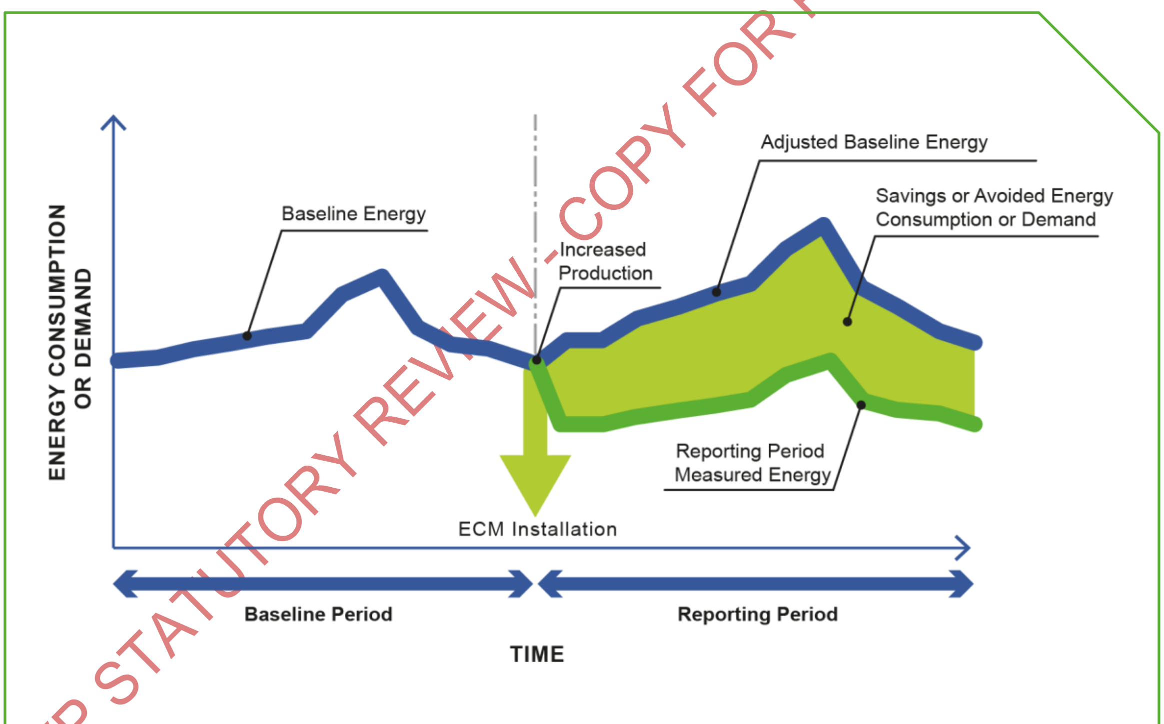

Figure 2. Savings or Avoided Energy Consumption or Demand

4.1. Measurement Boundary

Savings may be determined for an entire facility or a portion, depending upon the ECM characteristics and the purpose of the reporting.

- If the purpose of reporting is to verify the savings from equipment affected by the savings program, a measurement boundary should be drawn around that equipment and measurement requirements for the equipment within the boundary can then be determined. The approach used is the Retrofit-Isolation Option (Option A or B: Defined in Section 5). Determination of energy may be by direct measurement of energy-flow or by direct measurement of proxies of energy consumption and demand that can be used to reliably calculate energy consumption and demand.
- If the purpose of reporting is to verify and/or 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: Defined in Section 5.
- If the Baseline Period or Reporting Period data are unreliable or unavailable, energy data from a calibrated simulation program can take the place of the missing data, for either part or all of the facility. The measurement boundary can be drawn accordingly. The approach used is the Calibrated Simulation Option D: Defined in Section 5.
- Any energy effects occurring beyond the selected measurement boundary are called interactive effects. The magnitude of any interactive effects needs to be estimated or evaluated to determine savings associated with the ECMs. Although not preferred, interactive effects may be ignored in some cases provided the M&V Plan includes discussions of each effect, its likely magnitude and that the magnitude is small compared to savings from the primary effects.

4.2. Measurement Period Selection

4.2.1. Baseline Period

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

- Represent operating modes of the facility or the equipment during a normal operating cycle; the period should spin a full operating cycle from maximum energy consumption and demand to minimum.
- Include only time periods for which fixed and variable energy-governing facts are known about the facility.

  Note: *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, to properly derive routine and non-routine adjustments after ECM installation.*

- Coincide with the period immediately before commitment to undertake the retrofit.

  Note: *Periods further back in time may not reflect the conditions existing before retrofit and may therefore not provide a proper baseline for measuring the effect of just the ECM.*

- Support ECM planning.

Note: *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 the actual normal cycle length.*

4.2.2. Reporting Period

The developer of the M&V Plan and saving reports should determine the length of the reporting period. The reporting period should encompass at least one normal operating cycle of the equipment or facility, 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 one or several years. 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 to detect subsequent adverse changes in performance.

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

IPMVP-adherent savings can only be reported for reporting periods that use IPMVP-adherent procedures. If IPMVP-adherent savings are used as a basis for assuming future savings, future savings reports do not adhere to the IPMVP. See Section 8 of this document for more information on adherence.

4.3. Methods of 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:

Routine Adjustments

For any energy governing factors expected to change routinely during the reporting period (i.e. 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 several multiple parameters 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.

Non-Routine Adjustments

For those energy governing factors that are not usually expected to change (e.g., the facility size, the design and operation of installed equipment, the number of weekly production shifts, or the type or number of occupants) the associated static factors must be monitored for change throughout the reporting period.

Therefore, savings can be expressed as:

Savings =		(Baseline Period Energy	**(Eq. 2)**
	–	Reporting Period Energy)	
	±	Routine Adjustments	
	±	Non Routine Adjustments	

The adjustments are used to modify the baseline period energy data to reflect the same set of conditions as the post-ECM measured data. 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.

4.4. Savings Accounting Approaches

4.4.1. Reporting Period Basis or Avoided Energy Consumption or Demand

When savings are reported under the conditions of the reporting period, they can also be called savings of the reporting period, or avoided energy consumption. Savings stated as avoided energy consumption quantifies savings in the reporting period relative to what energy would have been without the ECM. When reporting savings under reporting period conditions, baseline period energy needs to be adjusted to reporting period conditions. The term forecasting is sometimes used to describe the adjustment of baseline period energy to reporting period conditions. This common style of estimating savings can be stated as:

Avoided Energy Consumption =		(Baseline Period Energy	**(Eq. 3)**
	±	Routine Adjustments to Reporting Period Conditions	
	±	Non Routine Adjustments to Reporting Period Conditions)	
	–	Reporting Period Energy	

This equation is often simplified to:

Avoided Energy Consumption =		Adjusted Baseline Energy	**(Eq. 4)**
	–	Reporting Period Energy	
	±	Non Routine Adjustments to Reporting Period Conditions	

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

The adjusted baseline energy is frequently found by first developing a mathematical model that correlates actual baseline period energy data with appropriate independent variables in the baseline period. Each reporting period's independent variables are then inserted into this baseline mathematical model to produce the adjusted baseline energy.

This process of calculating savings may be used in reverse, where the reporting period energy consumption and demand are adjusted to baseline conditions and savings are determined under baseline conditions. Although rare, it may make sense when more data are available in the reporting period to develop mathematical models of energy consumption and demand. The term backcasting is sometimes used to describe this adjustment of reporting period energy to baseline period conditions. For this style of savings, savings can be reported as:

Avoided Energy Consumption =		Baseline Period Energy	**(Eq. 5)**
	–	(Reporting Period Energy	
	±	Routine Adjustments to Baseline Period Conditions	
	±	Non Routine Adjustments to Baseline Period Conditions)	

This equation may be simplified to:

Avoided Energy Consumption =		Baseline Period Energy	**(Eq. 6)**
	–	Adjusted Reporting Period Energy	
	±	Non-Routine Adjustments to Baseline Period Conditions	

4.4.2. 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 (e.g., typical meteorological year weather) provides a type of savings often 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. Another term describing the process of stating savings under some different set of conditions than the baseline or reporting period is chaining.

Normalized Savings =		(Baseline Period Energy	**(Eq. 7)**
	±	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 adjustment 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 period energy to the chosen fixed conditions.

4.4.3. Adjacent Measurement Periods (On/Off Test)

When an ECM can be turned on and off easily, baseline period 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 adversely affecting the facility operation.

Such on/off tests involve 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 consumption and demand between the two adjacent measurement periods is the savings created by the ECM. Savings are 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	**(Eq. 8)**

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 consumption and demand when equipment or systems are turned on and off.

The adjacent periods used for the on/off test should be long enough to represent the 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 accidentally or purposely turned off when intended to be on. Efforts should be made to ensure the persistence of such ECMs.

4.4.4. Basis for Adjustment or Which Type of Savings

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

Avoided Energy Style of Savings

- 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 once and are not changed.

Normalized Savings

- Are unaffected by reporting period conditions since the fixed set of conditions are established once and are not changed.
- Can be directly compared with savings from other ECMs predicted under the same set of fixed conditions.
- Can only be reported after a full cycle of reporting period energy consumption and demand, so that the mathematical correlation between reporting period energy and operating conditions can be derived.

4.5. Operational Verification

Operational verification consists of a set of activities that help to ensure that the ECM is installed, commissioned and performing its intended function.

Operational verification serves as a low-cost initial step for assessing savings potential or verifying performance over time and should be included in the M&V Plan and precede other post-installation saving verification activities. Operational verification is not necessarily the responsibility of the person performing the M&V activities but should be verified and documented as part of an M&V effort.

A range of operational verification methods is outlined in Table 1. As noted in the table, selection of the best approach to operational verification depends on the ECM's characteristics, the level of uncertainty involved, and the magnitude of the savings at risk. Data collected during the operational verification may be used during actual M&V.

During an independent review of reported savings, in addition to field verification of the installation, the reviewer shall conduct activities needed to observe that the ECM is based on sound scientific principles and that independent evidence exists to support any ex-ante (pre-M&V) claims made regarding its efficacy.

Table 1. Operational Verification Approaches

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. (e.g., windows, insulation, passive devices)
Sample Spot Measurements	Achieved ECM performance can vary from published data based on installation details or component load.	Measure single or multiple key parameters for a representative sample of the ECM installations.
Short-Term Performance Testing	ECM performance may vary depending on actual load, controls or interoperability of components.	Tests for functionality and proper control. Measure key 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 operations.
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 Building Automation System (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.

Operational verification can be integrated into commissioning efforts, coordinating data collection and analysis tasks, the results of which can be used both to support the M&V quantitative efforts and determine proper performance of the ECMs. Over time, as the M&V effort continues into subsequent years of the reporting period, the operational verification efforts can continue to assess proper performance of the ECMs, helping to ensure persistence of savings year-after-year.

5. IPMVP Options

5.1. 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 boundaries described earlier. In addition, different methods of calculating savings are available. Each requires data on energy consumption, demand 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:

- Utility or fuel supplier invoices or reading utility meters and making the same adjustments to the readings that the utility makes.
- Special meters isolating an ECM or portion of a facility from the rest of the facility. Measurements may be periodic for short intervals or continuous throughout the baseline or reporting periods.
- Separate measurements of parameters used in computing energy consumption and demand.
- Measurement of proven proxies for energy consumption and demand.
- Computer simulation that is calibrated to some actual performance data for the system or facility being modelled.

If the energy parameter is already known with adequate accuracy or when it is more costly to measure than justified by the increase in certainty, 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).

If it is decided to determine savings at the facility level, Option C or D may be favored. 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	Definition	How Savings are Calculated	Typical Applications
A. **Retrofit-isolation: Key Parameter Measurement**	» Savings are determined by field measurement of the key parameter(s), which define the energy consumption and demand 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 values. Estimates can be based on historical data, manufacturer specifications or engineering judgment. » Documentation of the source or justification of the estimated value is required. The plausible saving error arising from estimation rather than measurement is evaluated.	» Engineering calculation of baseline period energy and reporting period energy from: short-term or continuous measurements of key parameter(s) and estimated values » Routine and non-routine adjustments as required. Key parameter(s) measured during both baseline and reporting period.	» A lighting retrofit where the power draw is the key parameter measured and secondly, lighting operating hours are estimated based on facility schedules and occupant behavior.
B. **Retrofit-Isolation: All Parameter Measurement**	» Savings are determined by field measurement of the energy consumption and demand and/or related independent or proxy variables of the ECM affected system. » Measurement frequency ranges from short-term to continuous, depending on the expected variations in savings and 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 consumption and demand. » 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 measure power

IPMVP Option	Definition	How Savings are Calculated	Typical Applications
			consumption and demand.
C. **Whole Facility**	» Savings are determined by measuring energy consumption and demand at the whole facility utility meter level. » Continuous measurements of the entire facility's energy consumption and demand are taken throughout the reporting period.	» Analysis of the whole facility baseline and reporting period (i.e., utility) meter data. » Routine adjustments as required, using techniques such as simple comparison or regression analysis. » Non-routine adjustments as required.	» Multifaceted energy management programs affecting many systems in a facility. Measure energy consumption and demand 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 consumption and demand of the whole facility, or of a sub-facility. » Simulation routines are demonstrated to adequately model actual energy performance in the facility. » This option requires considerable skill in calibrated simulation.	» Energy consumption and demand simulation, calibrated with hourly or monthly utility billing data. Energy end-use metering and metered performance data may be used in model refinement.	» Multifaceted energy management programs affecting many systems in a facility but where no meter existed in the baseline period. » Energy consumption and demand measurement, after installation of gas and electric meters, is used to calibrate a simulation. » Baseline period energy, determined using the calibrated simulation, is compared to a simulation of reporting period energy consumption and demand.

5.2. Options A & B: Retrofit-Isolation

5.2.1. General

Retrofit-isolation allows the narrowing of the measurement boundary 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 requires additional meters at the measurement boundary. Narrow measurement boundaries also introduce the possibility of *leakage* through unmeasured interactive effects.

Since measurement is less than the total facility, the results of retrofit-isolation techniques may not be fully apparent in 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 consumption and demand of the equipment affected by an ECM from the energy consumption and demand of the rest of the facility:

- » **Option A:** Retrofit-isolation: Key Parameter Measurement
- » **Option B:** Retrofit-isolation: All Parameter Measurement

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 which are 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 measurements to verify that the parameter is constant. Once proven constant, the frequency of measurement may be reduced or the measurement stopped. To maintain control on savings as measurement frequency drops, more frequent inspections or other tests might be undertaken to verify proper operations. In a project where the contractor is responsible for ECM performance risk but is not performing ECM operation and maintenance, the constant nature of the key parameter may be agreed to be proven constant after initial measurement with re-inspections conducted throughout the reporting period to validate the constant nature and value of the key parameter.

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.

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 once or short and occasional. Where a parameter may change periodically, the occasional measurements of the parameter should happen at times representative of the normal system behavior.

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 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.

5.2.2. 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 consumption and demand before the design of the ECM. Alternatively, meters may be installed to measure baseline performance for a 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.

5.2.2.1. Electricity Measurements

To measure electricity accurately, measure the voltage, amperage and power factor, or true Root Mean Squared (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. RMS values can be reported by solid-state digital instruments properly accounting for the net power wave distortions existing in alternating current circuits.

Measure electricity demands 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.

Electricity 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's load is metered following the power company's metering methodology, so that high yet short-duration peak loads which may show up differently in a moving interval than in a fixed interval are represented properly.

5.2.2.2. 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.

5.2.2.3. Best Applications

Retrofit-Isolation techniques are best applied when:

- 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 using Option C.
- Interactive effects of the ECM on the energy consumption and demand of other facility equipment can be reasonably estimated, or assumed to be insignificant.
- Possible changes to the facility, beyond the measurement boundary, would be difficult to identify or assess.
- The independent variables which affect energy consumption and demand are not excessively difficult or expensive to monitor.
- Sub-meters already exist to isolate energy consumption and demand of systems.
- Meters added at the measurement boundary can be used for other purposes such as operational feedback or tenant billing.
- Measurement of parameters is less costly than Option D simulations or Option C non-routine adjustments.
- There is no need to directly reconcile savings reports with changes in payments to energy suppliers.

5.3. Option A: Retrofit-Isolation, Key Parameter Measurement

5.3.1. General

Under Option A, Retrofit-Isolation: Key Parameter Measurement, energy quantities are defined by equations in Section 5. 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 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 baseline or reporting period is sufficient. The reporting period measurement of such a constant parameter can also be considered a measurement of its baseline value and vice versa.

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

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.

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

- » ECM reduces a constant load without changing its operating hours.
- » ECM reduces operating hours while load is unchanged.
- » ECM reduces both equipment load and operating hours.

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

5.3.2. Calculations

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 period energy or reporting period energy measurements may involve measurement of only one parameter under Option A, and estimation of the other parameters. Therefore in some cases the general equation may simplify to:

Option A Savings =		Hours of Use	
	x	(Baseline Period Measured Rate of Energy Use	**(Eq. 9)**
	–	Reporting Period Measured Rate of Energy Use)	

5.3.3. 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 reinspected 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 values. 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.

5.3.4. 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 *estimated value* 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.

5.3.5. Best Applications

Option A is best applied where:

- Estimation of non-key parameters may avoid possibly difficult non-routine adjustments when future changes happen within the measurement boundary.
- Uncertainty created by estimations is acceptable.
- Continued effectiveness of the ECM can be assessed by simple routine re-testing or re-inspection of key parameters.
- Estimation of some parameters is less costly than measurement of them in Option B or simulation in Option D.
- Key parameter(s) used to judge a project's or contractor's performance in computing savings can be readily identified.

5.4. Option B: Retrofit-Isolation, All Parameter Measurement

5.4.1. General

Option B, Retrofit-Isolation: All Parameter Measurement, requires measurement of energy quantities, or parameters, needed to compute energy using Equations 1 and 2 in Section 5. 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.

5.4.2. Calculations

Equations 1 and 2 in Section 4 are 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 baseline and reporting period measurements. Therefore, in some cases for Option B the general equation may simplify to:

Option B Savings =	**Baseline Period Energy** **– Reporting Period Energy**	**(Eq. 10)**

5.4.3. Best Applications

Option B is best applied where:

- Meters added for isolation purposes will be used for other purposes such as operational feedback or tenant billing.
- Measurement of the parameters is less costly than simulation in Option D.
- Savings or operations within the measurement boundary are variable.

5.5. Option C: Whole Facility

5.5.1. General

Option C 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.

Whole-building 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. Regression models describe how well independent variables explain the energy consumption, but do not account for all variations between the model and the actual consumption data. If savings are large compared to the unexplained variations in the baseline period energy data, then identifying savings will be easier. Also the longer the period of savings analysis after ECM installation, the more data are available, and the less significant is the impact of short-term unexplained variations.

As a rule of thumb, if only monthly billing data are available for energy consumption and demand, savings typically must exceed 10% of the baseline period energy if you expect to confidently discriminate the savings from the unexplained variations in the baseline data.

When short-time interval energy consumption data are available, the number of data points is much greater, and advanced mathematical modeling may be more accurate than the linear models used for monthly analysis. Consequently, methods using short-time interval data and advanced algorithms may be able to verify expected savings that are lower than 10% of annual energy consumption. In either case, an assessment of baseline model accuracy with expected savings and monitoring period duration is required.

Identifying facility changes that will require non-routine adjustments is the significant 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 period conditions. Such inspections may be part of regular monitoring to ensure that the intended operating methods are still being followed. A lower cost alternative, most applicable to smaller projects or facilities, can be to track energy performance over time, normalized for operating conditions, and inspect the facility for changes when adjusted performance shows a persistent change.

5.5.2. 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 saving 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 totaled 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*.

5.5.3. 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(s). 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 consumption and demand. However, where there is no downstream meter, inventory-level adjustments for each invoice period should supplement the invoices.

5.5.4. 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 period data. Parameters, which have a significant effect on the baseline period energy, should be included in the routine adjustments when determining savings using one of the following equations:

Savings =		(Baseline Period Energy	**(Eq. 11)**
	–	Reporting Period Energy)	
	±	Routine Adjustments	
	±	Non Routine Adjustments	

Avoided Energy Consumption =		Adjusted Baseline Energy	**(Eq. 12)**
	–	Reporting Period Energy	
	±	Non Routine Adjustments to Reporting Period Conditions	

Normalized Savings =		(Baseline Period Energy	**(Eq. 13)**
	±	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 during the same time period as the energy data.

5.5.5. Calculations & 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 Period Energy	**(Eq. 14)**
	–	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 can also be based on interval data – and often includes factors derived from regression analysis, correlating 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 variations.

Option C should usually use complete years (e.g., twelve, twenty-four or thirty-six months) of continuous data, during the baseline period, and continuous data during the reporting periods. For short-time interval data, fewer months of data may be used, however care should be taken to assure that the data range is representative of the entire baseline year. Models, which use other numbers of months (e.g., nine, ten, thirteen, or eighteen months), can create statistical bias by under or over-representing unusual modes of operation. Such models should be checked for bias.

Metered data can be hourly, daily or monthly whole-facility data and may be combined into longer time intervals, such as daily, to limit the number of independent variables required to produce a reasonable baseline model, without significantly increasing the uncertainty in computed savings. When verifying demand savings, it may be sufficient to use only previous days of similar weather conditions when developing demand models. Many statistical models are appropriate for Option C. To select the one most suited to the application, consider statistical-evaluation indices, such as Coefficient of Variation of the Root Mean Squared Error (CV{RMSE}), Mean Bias Error (MBE) or published statistical literature can help demonstrate the statistical validity of the selected model.

5.5.6. Metering

Whole-facility energy measurements can use the utility'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 the sale of energy commodities.

The energy supplier's meter(s) may be equipped or modified to provide an electrical 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.

5.5.7. 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.

5.5.8. Best Applications

Option C is best applied where:

- Energy performance of the whole facility will be assessed, not just the ECMs.
- There are many types of ECMs in one facility.

- ECMs involve activities whose individual energy consumption and demand is difficult to separately measure.
- Savings are large compared to the variance in the baseline and reporting period data.
- Retrofit-isolation techniques (Option A or B) are excessively complex and costly.
- Significant future changes to the facility are not expected during the Reporting period.
- System of tracking static factors can be established to enable possible future non-routine adjustment.
- Reasonable correlations can be found between energy consumption and demand and other independent variables.

5.6. Option D: Calibrated Simulation

5.6.1. General

Option D: Calibrated Simulation, involves the use of building energy simulation software to predict facility energy use, typically when a baseline does not exist. When metered data for the baseline or existing condition is available, the simulation model is calibrated so that it predicts the energy and load shape that approximately matches the actual metered data.

Option D may be used to assess the performance of ECMs for the whole building, akin to Option C. However, the whole-building simulation model can also be used to provide an estimate of 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. For this application, the system's energy consumption and demand must be isolated from that of the rest of the facility by appropriate meters, which will be used for the calibration of the simulation model.

5.6.2. Types of Simulation Programs

Whole-building simulation programs usually use hourly calculation techniques. Utilizing simulation software packages that are widely used and have been evaluated by ASHRAE Standard 140 are preferred. However proprietary simulation software may also be used if algorithms are transparent and well documented. System-level simulation models may be used if they meet the above criteria and account for ECM interactions. Other types of special-purpose programs may be used to simulate energy use associated with the operation of devices or industrial processes.

The software used must be well understood by the user. The software should be capable of simulating the use type, the space types as well as the project ECMs. Due to the wide variety of available software, it is prudent to receive acceptance by the owner or project authority of the proposed modelling program before commencing analysis.

5.6.3. Calibration

Savings determined with Option D are based on physical models and numerical solution techniques used to predict building energy consumption and demand. The accuracy of the savings depends on user proficiency, model robustness and the level of calibration.

When calibrated, the simulation model should reasonably predict the load shape and energy use of the facility or system. This is determined by comparing model results to measured performance data, independent variables and static factors.

Nominally, calibration of the whole building simulations is performed with twelve consecutive months of utility billing data over a stable operating period. In a new building, this may not occur until after several months when occupancy and operation stabilize. The calibration time period and data to be utilized should be documented in the M&V Plan.

Calibration data might include operating characteristics, occupancy, weather, loads and equipment efficiency. Parameters should be measured at an appropriate interval, day, week, month, or extracted from existing operating logs or trend data logs. The accuracy of meters should be verified for critical measurements. When possible, other variables, influential parameters, such as, building ventilation and infiltration rates, should also be measured. The level of calibration should be established in the M&V Plan and reflect the level of effort and accuracy justified for the project.

Following the Calibration Data Collection, perform the Calibration Steps below:

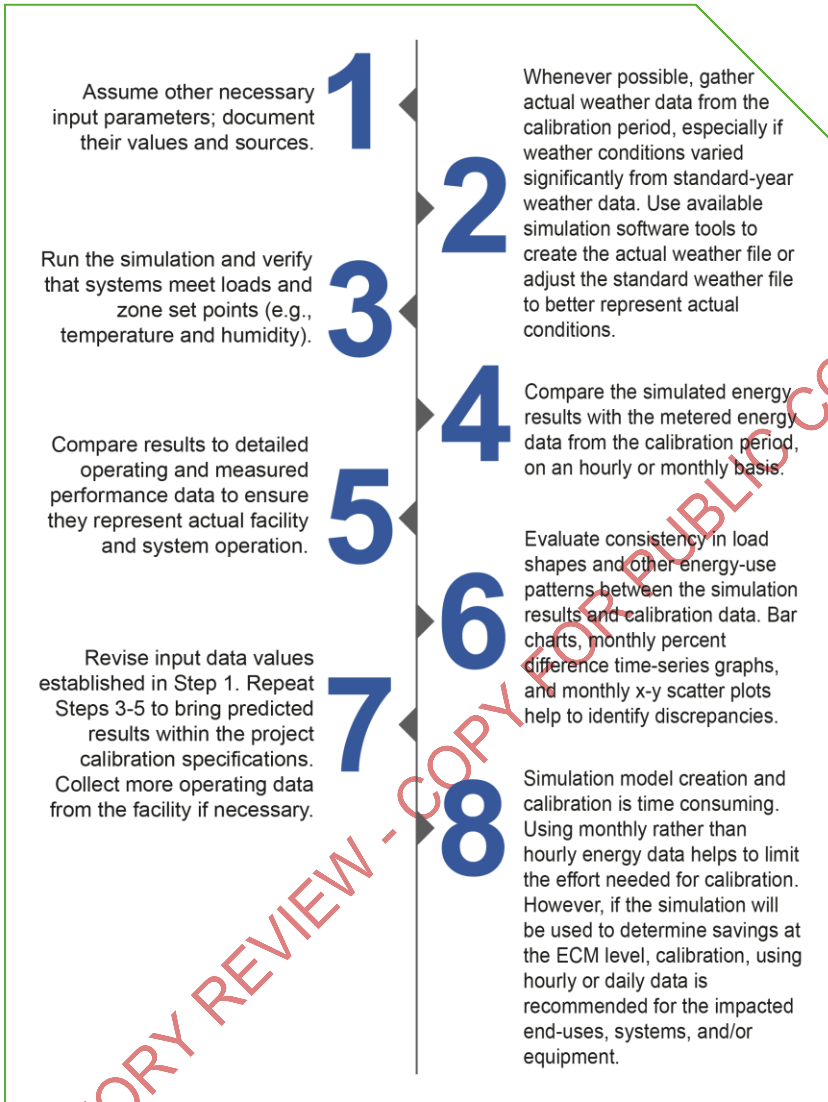

Figure 3. Calibration Steps

> **Note:** *Accurate computer modelling and model calibration are the major challenges associated with Option D implementation.*

To balance costs with accuracy, the following points should be considered:

- Simulation analysis should be conducted by trained personnel, experienced with the software and calibration techniques.
- Record survey data, monitoring data, and assumptions used to define input values. The calibrated simulation model should be saved in paper and electronic files. The simulation software release version should be recorded and saved to support quality assurance reviews.
- Document the specific changes made to the simulation model to represent each ECM's impact.

- When possible for new construction projects, retain the building energy modeler that created the as-designed model to create the calibrated, *as-built* and adjusted baseline models.

5.6.4. Calculations

Savings can be determined using calibrated simulation results representing the baseline period and the reporting period. If the baseline period does not exist (e.g., new construction), the reporting period calibrated model can be used to develop the baseline model. If the baseline period does exist, a calibrated model representing existing building conditions can be developed to predict the impact of the ECMs. After ECM installation, the reporting period energy consumption and demand will be used to calibrate the initial baseline model with the predicted ECMs (e.g., the *as-designed* model for new construction) to develop the reporting period model. Once calibrated, the ECMs will be removed from the model to create the baseline model. The model represents the existing building under the reporting period conditions. If it is desired to report savings under normal conditions, the reporting period calibrated model would be modified to represent normal conditions (e.g., normal weather conditions, other normal independent variables) then the ECMs would be removed to develop the baseline model.

For projects that develop a hypothetical baseline model (e.g., code-compliant baseline for a new construction project), the baseline model for M&V must be developed from the calibrated, reporting period model with ECMs removed, as described above.

In either case, the model(s) and measured energy data must be under the same set of operating conditions, similar to Option C.

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 period and reporting period models. The same savings will be determined from the two equations for any given set of data and simulations.

Savings =		Baseline Period Energy from the Calibrated Model [without ECMs]	**(Eq. 15)**
	–	Reporting Period Energy from the Calibrated 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 Period Energy from the Calibrated Model [baseline without ECM]	**(Eq. 16)**
	–	Actual Reporting Period Energy	
	±	Calibration Error in the Corresponding Calibration Reading	

5.6.5. On-Going Savings Reporting

If a multi-year performance evaluation is required, models must be recalibrated each year of the reporting period. As an alternative, Option D may be used for the first year after the ECMs are installed. In later years, Option C may be applied with the baseline period based on the metered data from the reporting period first year of steady operation. In this case, Option C is used in preceding years to track savings persistence.

5.6.6. Best Applications

In general, Option D is used when other options are not feasible. It is best applied where:

- Baseline period energy data are unavailable or unreliable, such as:
  - New construction project
  - Facility expansion needing to be assessed separately from the rest of the facility
- 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.
- There are too many ECMs to assess using Options A or B.
- Performance of each ECM will be estimated individually within a multiple ECM project, but the costs of Options A or B are excessive.
- Interactions between ECMs are complex and significant, making the isolation techniques of Options A and B impractical.

6. IPMVP Adherent M&V Plan and Report

This chapter describes the requirements for developing and implementing an adherent M&V Plan and report.

6.1. IPMVP Adherent Plan

IPMVP does not currently provide for a formal certification of project specific M&V Plans. However, guidance provided here may be used by a project engineer to develop or review a M&V Plan for IPMVP adherence. An adherent M&V Plan is one that meets all of the criteria presented in items 1 through 14 below. Additional adherence requirements for Option A and Option D projects are included after the criteria for all plans. An M&V Plan adherence criteria checklist can also be found on EVO's website.

A key component towards IPMVP adherence involves the development of a clear and transparent project-specific M&V Plan that describes various measurements and data to be gathered, analysis methods employed and verification activities that are conducted to evaluate the performance of a measure or a project. An adherent M&V Plan will help ensure that the measure or the project can realize its maximum potential and that the savings can be verified with adequate certainty. For performance contract projects where the M&V Plan defines how savings will be verified to prove that the contractual savings guarantee has been met and to validate associated payments, an adherent M&V Plan needs to be developed and agreed to as part of the final contract approval and/or before the installation of the project ECMs.

The following describes the essential requirements of an IPMVP adherent M&V Plan.

6.1.1. Facility and Project Overview

M&V Plan should provide an overall description of the facility and the proposed project along with the list of all the measures that are included as part of the project. This section should also include references to any energy audit reports or other analysis that was used to scope the project.

6.1.2. ECM Intent

This section of the M&V Plan should provide a clear understanding of each measure's scope and intent. At a minimum, this section should include:

- A measure description
- How the measure saves energy or other resources (e.g., improves efficiency, reduces operating hours, etc.)
- Affected equipment inventory
- Expected savings

6.1.3. Selected IPMVP Option and Measurement Boundary

The M&V Plan needs to specify the IPMVP option that will be used to evaluate savings. This section also needs to identify the measurement boundary for saving determination. The boundary may be as narrow as the flow of energy through a pipe or wire, or as broad as the total energy consumption and demand across many facilities. This section should also describe the nature of any interactive effects beyond the measurement boundary together with their possible effect on project savings. Quantified interactive effects should also be included in this section with appropriate justification.

6.1.4. Baseline: Period, Usage and Conditions

This section of the M&V Plan documents the facilities or system's baseline utility demand and consumption along with corresponding influencing parameters, within each measurement boundary.

The baseline description must be well-documented. The baseline data may come from many sources such as short-term metering or spot measurements or from other sources such as manufacturer specification sheets. The extent of the needed information is determined by the selected M&V Option, measurement boundary chosen or the scope of the savings determination.

Baseline documentation should include the following information:

Identification of the Baseline Period

This is the time period over which the facility or system baseline conditions are assessed and documented. This baseline period is often a year but can be any period depending on the specific M&V needs.

Baseline Utility Consumption and Demand Data

The baseline utility may be billing data if an Option C approach is being used, or could be field collected interval data, or spot measurement data if Options A or B are being used. This includes the data over the measurement period. These data can be used to extrapolate over the entire baseline period as discussed above and this analysis should also be included. These data are normally considered to be the *dependent* variable.

Utility Influencing Variable Data

These utility influencing data need to be gathered corresponding to the time period for which utility data were collected. This may include variables such as production data, ambient temperature, baseline equipment speed, pressure or any other variable collected through spot measurements, short-term or long-term metering. These data are normally considered to be the independent variable or variables that affect the dependent variable discussed above.

Operating Conditions

Define the prevailing operating conditions corresponding to the dependent and independent variables (e.g., Baseline Utility Consumption and Demand Data, Utility Influencing Variable Data) during the Identification of the Baseline Period. These prevailing conditions (i.e., also known as static factors) are assumed to remain constant, but may change and have to be addressed as part of non-routine adjustments if needed. Examples of static conditions may include, but not be limited to the following:

- Occupancy type, occupancy density and run times.
- Operating conditions (e.g., set points, lighting levels, ventilation levels) for each baseline period and season.
- Significant equipment problems or outages during the baseline period:
  - In some cases, existing systems or facilities may not function properly, meet code, or otherwise may not be reflective of the true baseline conditions. In these cases, the baseline may be adjusted so that it reflects the operation while meeting code or operation after needed repairs.
- Baseline adjustments may be made, for example, on systems that are not providing adequate ventilation. System changes may include equipment efficiency, capacity, operating sequence or any other element of the measure that results in changes in energy use.
- Identify planned changes to conditions that affect the baseline:
  - Planned changes may include any number of things such as increase in occupancy levels, adding a shift, or increased lighting levels.

6.1.5. Reporting Period

The reporting period is a selected interval for evaluating and quantifying the post-installation performance of the measure. The M&V Plan shall identify the reporting periods for which the measure or a project is being evaluated. This may be for a short period of time right after the installation of the measure to ensure that the measure is performing as intended or it could be a longer time at periodic intervals such as a year, multiple years, or other time periods.

In cases where the baseline period and reporting period are not of the same length, it is important to explain how the time frames are normalized so the baseline and reporting period energy consumption and demand are compared evenly and reliably.

In a performance contract, the performance period refers to the duration of the project guarantee and is made up of numerous reporting periods. Normally the contractor is required to report on the performance of the project and the ECMs on a regular basis for the entire duration of the performance period.

6.1.6. Basis for Adjustment

The operating conditions that affect energy consumption may differ between the baseline and reporting periods. It is important to make adjustments to account for these changes in operating conditions.

The M&V Plan should provide details outlining how the baseline and/or reporting period energy consumption and demand will be adjusted to allow for valid comparison and saving calculation. The basis for adjustments can be made by:

- Projecting the baseline energy consumption and demand to reporting period conditions.
- Projecting reporting period energy consumption and demand to baseline operating conditions.

- Projecting both the baseline and reporting period energy consumption and demand to standard conditions (e.g., Typical Meteorological Year TMY).

The conditions for the basis for adjustment determine whether savings are reported as avoided energy or as normalized savings.

Another basis of adjustment is to account for baseline equipment problems or code compliance issues that must be addressed prior to ECM implementation. In these cases, the baseline may be adjusted so that it reflects the operation while meeting code or operation after needed repairs. If the baseline is to be adjusted, include a description of the exact adjustments to the algorithms, variables or terms that affect baseline energy use.

A third basis of adjustment is to account for factors that are not expected to change (i.e., static factors) during the reporting period. However, in the likelihood that these factors change, their effects need to be accounted through proper non-routine adjustment procedures. Examples may include adding a new shift to production or increasing the operating hours that are not part of the baseline or the installed measure.

6.1.7. Calculation Methodology and Analysis Procedure

The M&V Plan needs to specify data analysis procedures, model descriptions and assumptions that are used to calculate savings for each of the reporting periods.

For each model used, identify and define all independent variables, dependent variables, and other model-related terms. Report all coefficients, constants, statistical metrics (CV{RMSE}, MBE, R^2, t-statistic, etc.) or other model elements or terms. Report the range of independent variables over which the models are valid.

6.1.8. Energy Prices

The M&V Plan should also specify the utility prices, or tariffs that will be used to calculate the cost savings associated with the measure or project, and how the monetary value of savings will be adjusted if utility prices change during the life of a measure or a project. The plan should clearly define and report any assumed or stipulated values such as inflation and/or escalation rates, utility price increases or other variables that affect M&V results.

6.1.9. Meter Specifications

The plan should specify the metering points that will be used to gather M&V data that includes both spot and continuous metering. For non-utility meters, the M&V Plan should specify:

- Meter - type, make, model and characteristics
- Meter specifications including accuracy and precision
- Meter reading and witnessing protocol
- Meter commissioning procedure
- Calibration procedure/process
- Method of dealing with lost data and data transfer

6.1.10. Monitoring Responsibilities

The plan should assign responsibilities for collecting, analyzing, archiving and reporting the data. Management of M&V data should be assigned to the party that is qualified to efficiently and effectively access, manage and provide data sets. Monitored data that must be managed includes:

- Energy data
- Independent variables
- Static factors within the measurement boundary
- Periodic inspection findings

6.1.11. Expected Accuracy

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

6.1.12. Budget

The M&V Plan should include the budget and the resources required for saving determination, costs for both the initial setup and ongoing tasks for evaluating, documenting and reporting the performance for each of the Reporting periods.

6.1.13. Report Format

The plan should specify how results will be reported and documented for each of the Reporting periods including the frequency of reporting.

> **Note:** *Refer to Section M&V Reports for details.*

6.1.14. Quality Assurance

The M&V Plan should include quality-assurance procedures and processes that will be used for the baseline and post-retrofit M&V data collection, calculations, saving reports and any interim steps in preparing reports. Quality assurance should include inspections at regular frequencies to ensure that the measure and equipment continue to be operated per the contract.

6.2. Additional M&V Plan Requirements for Option A

6.2.1. Justification of Estimates

The M&V Plan should clearly identify the variables to be estimated as part of the savings calculation. This must include the actual values used and source of the 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.

6.2.2. Periodic Inspections

The plan should specify the periodic inspections that will be performed in the reporting period to verify that equipment is still in place and operating as assumed.

6.3. Additional M&V Plan Requirements for Option D

6.3.1. Software Identification

The M&V Plan should report the name and the version number of the simulation software that is used to calculate savings.

6.3.2. Input/Output Data

The plan should provide copies of the input files, output files, and weather files, or weather file identification, used for the simulation, including any post-processing or presentation development methods and calculations.

6.3.3. Measured Data

The M&V Plan should describe the process of obtaining any measured data including which input parameters were measured and which input parameters were estimated. The actual measured data should also be reported and raw data should be archived and made available as needed. This may include interval data or utility-provided bills.

6.3.4. Calibration

The plan should report the energy and operating data used for calibration including the calibration requirements (e.g., CV{RMSE}, MBE, etc.) and the accuracy with which the simulation results match the calibration energy data. Data should be provided at a minimum of one month (i.e., billing period) intervals, and more resolution is preferred.

6.3.5. Future Changes

The M&V Plan should provide a description of the method for making relevant non-routine adjustments. Non-routine adjustments may require revising the model and recalculating baseline and post-installation energy use and savings.

6.4. M&V Reports

Periodic M&V reports are prepared as a means to document the overall performance of the measure and project using procedures outlined in the M&V Plan. The frequency and the format for these M&V reports will also be included in the M&V Plan. The report will include at a minimum the following information:

- Project background
- ECM description
- M&V Option chosen for the ECM or project as part of the M&V Plan
- Reporting period start and end dates
- M&V activities conducted during the reporting period, including:
  - Start and end time for the measurement period
  - Energy use data
  - Data for independent and static variables
  - Description of inspection activities conducted
  - Verified saving calculations and methodology
  - Provide detailed description of data analysis and methodology
  - Provide an updated list of assumptions and source of data used in the calculations
  - Provide details of any baseline or saving adjustments including both routine and non-routine adjustments to account for changes
  - Provide details of utility costs used to calculate the reported savings
  - Clear presentation of verified energy, cost savings and comparison to the proposed savings

7. Adherence with IPMVP

The IPMVP represents a framework of terminology and methods for properly assessing savings in energy or water consumption and demand. The IPMVP guides users in developing M&V Plans and Reports for specific projects. The IPMVP is written to allow maximum flexibility in creating and implementing M&V procedures, while adhering to the principles of accuracy, completeness, conservativeness, consistency, relevance and transparency (see Section 3).

M&V represents a process implemented to assure savings are verified according to the application of IPMVP's procedures. A typical M&V process is illustrated in Figure 4 and described by the following steps:

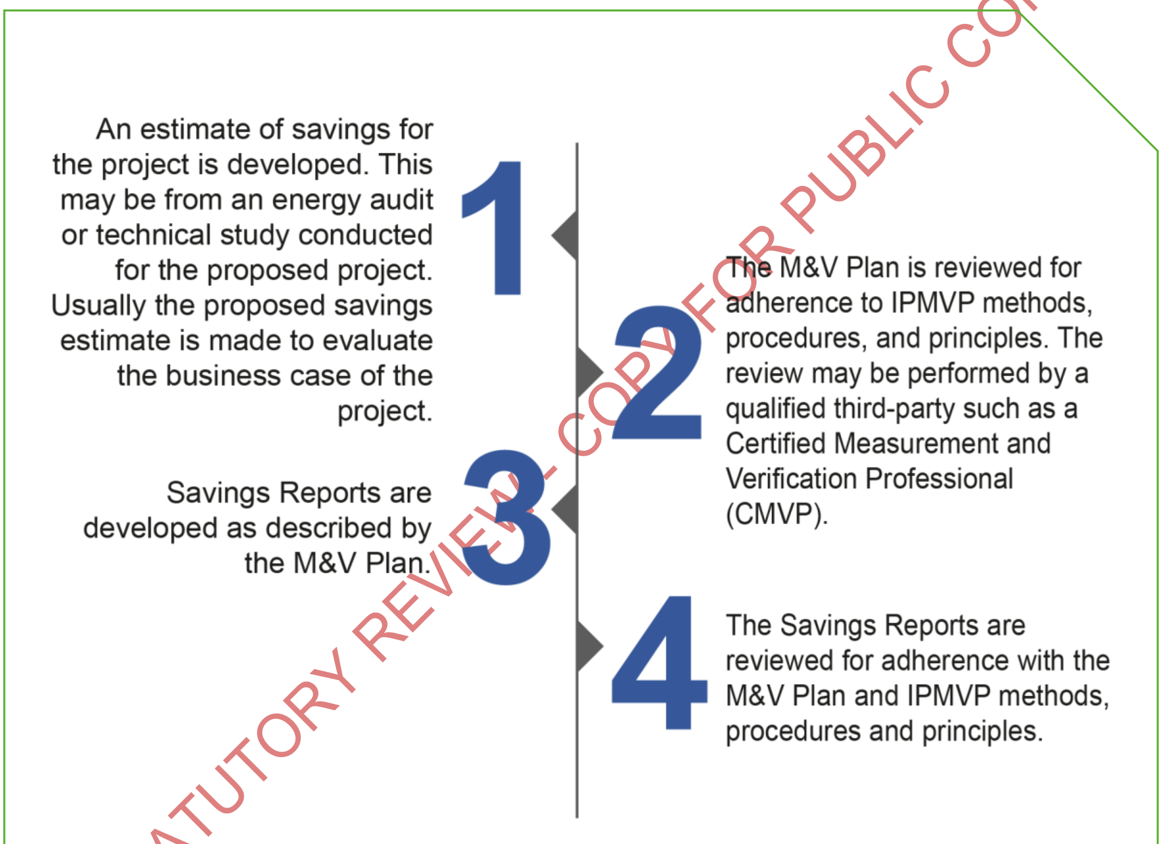

Figure 4. Typical M&V Process Steps Description

This results in an adherent project through the latest reporting period.

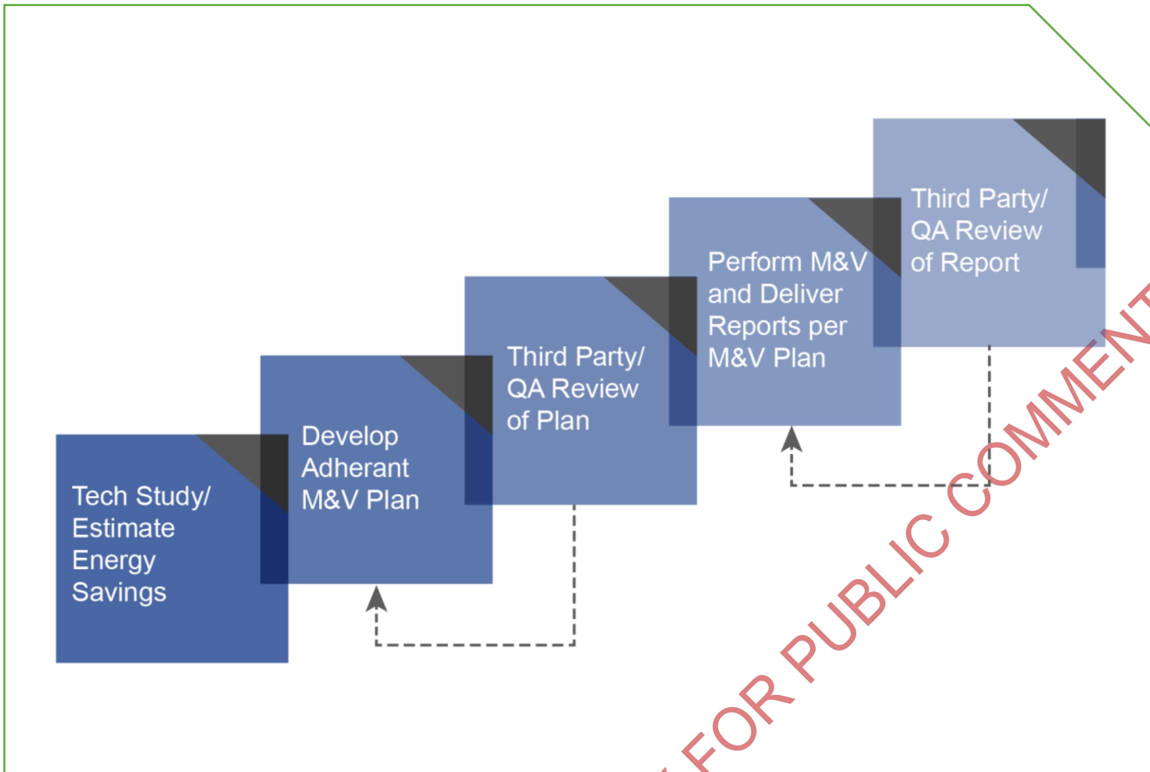

Figure 5. Flowchart of M&V Process with Typical Adherence Activities

Users claiming adherence with IPMVP must:

- 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.

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.
- Includes all information mentioned in *the M&V Plan* Section 7.
- Defines the contents of saving reports and the frequency that savings will be reported.
- Is approved by all parties interested in adherence with IPMVP.
- Is consistent with the Principles of IPMVP.

Implement the approved IPMVP adherent M&V Plan and assure its procedures are followed according to the Principles of IPMVP. This may include conducting a quality assurance review of all M&V activities, including inspections, measurements, calculations and reports. For each project, quality assurance procedures are described in the M&V Plan. A knowledgeable and experienced professional should conduct the review process.

EVO recommends that a qualified professional, such as a Certified Measurement and Verification Professional (CMVP), be used to develop and oversee implementation of M&V Plans and activities.

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 Core Concepts." 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 …”.