Efficiency Valuation Organization

IPMVP

GENERALLY ACCEPTED M&V PRINCIPLES

International Performance Measurement and Verification Protocol
(October 2018)

Foreword

We would like to thank the Efficiency Valuation Organization for allowing us to use their excellent materials on M&V and the IPVMP in this educational document.

The goal of this document is to help members of the SkyFoundry community interpret IPMVP requirements and align those with SkySpark capabilities and feature sets.

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International Performance Measurement and Verification Protocol
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V1.0

Applying SkySpark to Meet IPMVP Generally Accepted M&V Principles

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Using this Document

Throughout this document we provide commentary on SkySpark features sets and capabilities that are relevant to the IPVMP topics on the corresponding page.

Monitoring & Verification, and IPMVP are comprehensive topics and a full assessment of the ways in which SkySpark helps professional address these needs requires more information than can be presented in this document, however, we believe this will be a helpful introduction to the topic.

SkyFoundry provides extensive product information and training resources to help professionals further evaluate application of SkySpark in M&V and IPVMP practices.

1. 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 that 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 and 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.

Accuracy

One of the benefits SkySpark offers is to approach energy cost calculations with a range of precision options. By doing so, the precision appropriate for the application and project budget can be selected in keeping with the principle of being "*as accurate as can be justified based on the project value*" to keep costs and effort "*small relative to the monetary value of the savings being evaluated*". As an example, energy costs can be calculated using a static $/kwh factor or can be calculated precisely using the SkySpark's Tariff Engine which allows detailed charges to be entered.

Collection of tariff data can often be time consuming. The need for precision in energy cost calculations should be considered based on the project value and potential savings value.

Consistency

SkySpark includes features that allow for energy consumption data to be normalized across facilities based on common factors such as building size and weather factors or based on project-specific factors. Normalization factors are fully customizable in SkySpark and can take advantage of SkySpark's advanced math capabilities as needed using our Axon scripting language.

Also related to the consistency topic, all data, KPI's, calculated costs and analytic results can be easily exported in standard formats including csv, xml, Excel®, JSON and others for use by energy management professionals that wish to use different tools for data analysis.

Transparency

SkySpark provides the ability to export all calculations, algorithms, KPI definitions, normalization formulas, data used, and analytic results in a variety of standard formats for project documentation and review purposes. Export formats include: CSV, JSON, XML, Zinc and Trio.

2. 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.

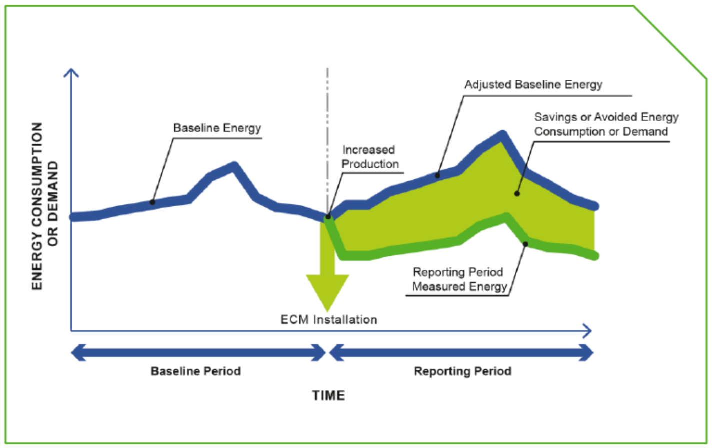


Figure 1. Savings or Avoided Consumption or Demand

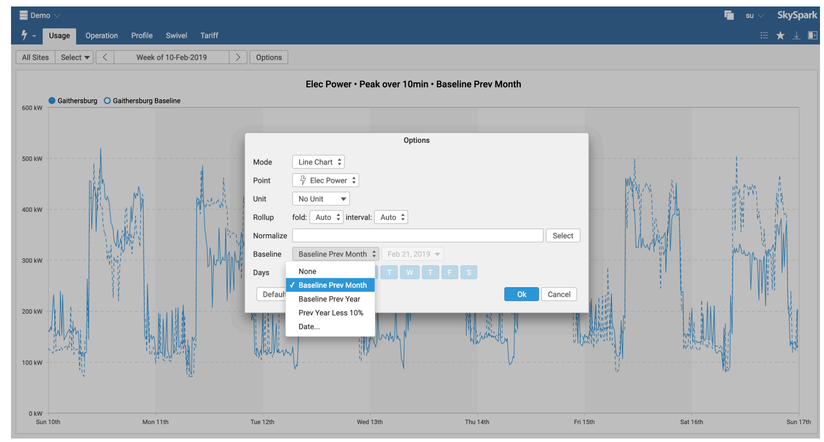
2.1. Measurement Boundary

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 a retrofit isolation option (Option A or B, defined in Section 3). 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 their magnitude.

Savings Calculations – Baseline Capability

SkySpark software includes the ability to utilize baselines for presentation and analysis of energy performance across any period of time. It includes the ability to employ common baselines such as last month, last year, specified time ranges with a simple click, AND allows for the creation of custom baselines based on math calculations and data sets generated by external energy modeling tools. Projected energy performance data sets generated by external modeling tools can be imported and treated as virtual meters for comparison against actual energy performance. SkySpark allows easy selection of baselines, and visualization of baselines and actual energy data. See below:



Measurement Boundaries

SkySpark supports definition of measurement boundaries through direct measurement via the use of submeters (where available), and via the creation of calculated proxies (virtual meters). SkySpark's full function math capabilities allow for sophisticated calculation of submeter proxies.

2.3. 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 (e.g., 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.

2.4. Savings Accounting Approaches

2.4.1. Reporting Period Basis of Avoided Energy Consumption or Demand

When savings are reported under the conditions of the reporting period, they can also be called avoided energy consumption. Savings stated as avoided energy consumption quantifies them in the reporting period relative to what energy usage would have been without the ECM. When reporting savings under reporting period conditions, baseline period energy needs to be adjusted to the reporting period's 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.

Methods of Adjustment

SkySpark enables the implementation of both routine and non-routine adjustments. Adjustments based on factors such as weather, production volume, facility size, number of weekly production shifts and occupancy are handled with SkySpark's normalization features and can also be used in Key Performance Indicators (KPI's). Normalization can be accomplished based fixed/static numerical factors (like building size), actual data (degree days measured by a weather service or sensors) or calculations using SkySpark's extensive math capabilities which include: trigonometric functions, statistical functions, linear regression, frequency domain analysis, matrix math, calculus, and of course, basic arithmetic. Creation of customized KPI's and normalization factors is accomplished with SkySpark's Axon scripting language which includes a full math package.

SkySpark also supports manual entry of data via Forms which are useful to enter data that is not available via sensors or digital data feeds. For example, number of weekly production shifts, or production output (units, pounds, volume, etc.) might be entered by a production manager via a form. The entry date, as well as new and old value are recorded.

Savings Accounting Approaches

SkySpark provides the ability to account for savings in the methods described to the left. Baseline periods can be adjusted for conditions affecting energy use (weather, changing occupancy periods and other factors). Energy costs for both baseline energy use and actual can be calculated based on fixed factors (for example $/kwh, or more comprehensive factors based on all charges in complex tariff rates. Delta between baseline and Actual can be shown with a variety of reporting tools including: line graph, donut chart, and delta baseline view. The energy savings/avoided costs can be shown in text format on reports. See examples on following page.

One of the most powerful capabilities of SkySpark is the ability to calculate the cost associated with faults, deviations from expected performance and anomalies to show the potential cost savings available before ECMs are implemented. See section on Operational Verification for examples.

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, this 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 method, 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	

2.4.2. 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.

2.5. Operational Verification

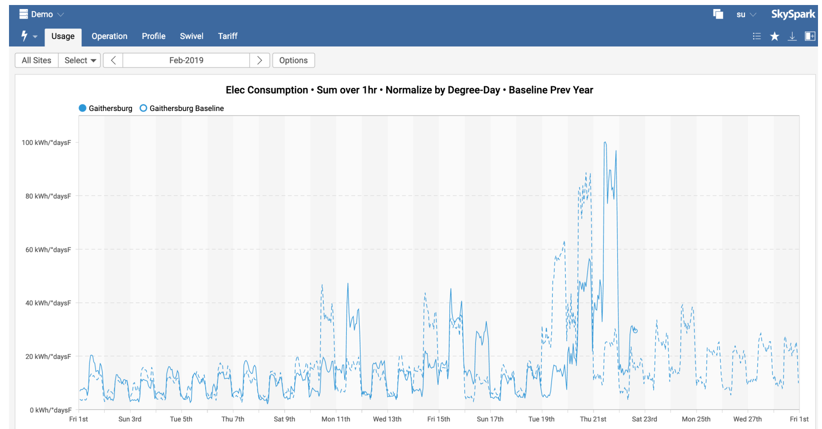
Operational verification consists of a set of activities that help to ensure that the ECM is installed, commissioned and performing its intended function. Operational verification serves as a low-cost initial step for assessing savings potential or verifying performance over time and should be included 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

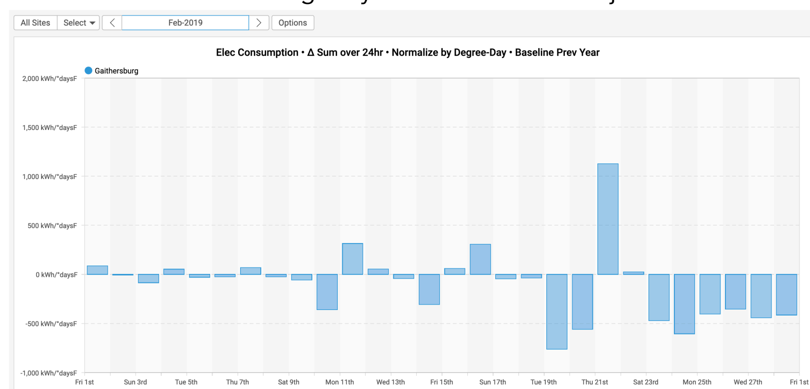
Savings Accounting Approaches

SkySpark Views Showing Baseline vs actual Usage and Costs

Line chart:



Delta Baseline View showing daily results of actual vs adjusted baseline:



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

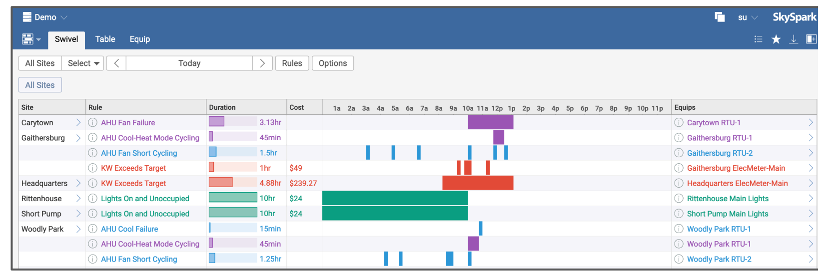
Operational Verification Approach	Typical ECM Application	Activities
Visual Inspection	ECM will perform as anticipated when properly installed. Direct measurement of ECM performance is not possible.	View and verify the physical installation of the ECM. (e.g., windows, insulation, passive devices)
Sample 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 quantification 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.

Operational Verification

One of SkySpark's most powerful features is the ability to apply analytics rules/algorithms against trended (or near real time) data to automatically identify deviations in the expected performance of ECM's. This capability dramatically reduces the cost and effort needed with manual verification and testing processes.

Analytic rules look for faults, deviations, anomalies, trends like energy drift, loss of efficiency, etc. As soon as issues are detected, SkySpark automatically generates rich informative views showing issues without the need to manually assemble reports, charts or graphs. See example below.



In the View above, SkySpark shows the issues detected in a portfolio of facilities along with: Rule description (note: detailed help is also provided by clicking on the "I" icon associated with each rule); duration shown as a bar graph; calculated cost; timelines showing the actual pattern of the deficiency; and identification of the offending equipment system (rightmost column).

SkySpark can also send commands to control systems to drive a process known as "**active commissioning**" where SkySpark introduces changes or disturbances to the control system while analytic rules verify that the system responds as expected.

SkySpark provides the ability to move from "one time" commissioning to true "monitoring-based commissioning".

3. IPMVP Options

3.1. Overview of IPMVP Options

IPMVP provides options for developing and implementing a high-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 utility meter readings, 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.

Support for IPMVP Options A, B, C and D

All of the energy quantities techniques listed to the left can be used with SkySpark.

Utility or fuel supplier invoices can be manually entered using “Forms” or imported if those data are available in digital form. SkySpark can collect data from utility meters, utility provided web services (API’s), permanently installed submeters, or temporary metering devices.

SkySpark supports a variety of data acquisition connectors: Bacnet IP, Modbus TCP, Obix, Haystack, SNMP, Sedona, OPC UA, MQTT, SQL, CSV import (manual batch or automated), and a REST API.

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 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 (e.g., 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.

Support for IPMVP Options A, B, C and D

Option A: Retrofit Isolation

SkySpark supports the use of continuous energy measurement via meters and submeters, as well as the use of manually collected energy data which can be entered using SkySpark's "Form" feature, and data collected from temporary meters/data loggers. All energy analysis features (normalization, adjustments, virtual meters calculations, etc.) are supported. Factors such as occupancy hours can be collected from control systems where available or manually entered.

Option B: Retrofit Isolation: All Parameter Measurement

SkySpark supports the use of continuous energy measurement via meters and submeters, as well as the use of manually collected energy data which can be entered using SkySpark's "Form" feature, and data collected from temporary meters/data loggers. All energy analysis features (normalization, adjustments, virtual meters calculations, etc. are supported.

Option C: Whole Facility

SkySpark supports all of the calculation methods shown to the left. It can collect and store energy data from metering devices or import that data from other sources such as utility web services or file-based data. It provides baseline, normalization and regression analysis tools.

Option D: Calibrated Simulation

Data generated by external simulation software can be imported into SkySpark in a variety of standard formats. Once imported, simulation data can be treated as virtual meters which provide all of the functionality of actual meters. Data can be compared between facilities and different time periods, normalized for typical factors (weather, facility size), or custom, project-specific factors, compared to calculated or actual baseline data, and converted to cost using simple cost factors or complex tariff rate charges.

4. IPMVP-Adherent M&V Plan and Report

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

4.1. 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 an 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 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.

4.1.1. Facility and Project Overview

The 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.

4.1.2. 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

4.1.3. 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.

4.1.4. Baseline: Period, Usage and Conditions

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

IPMVP Adherent Plan

SkyFoundry's SkySpark software does not play a direct role in the development of the overall M&V plan for a project. This section of the EVO document provides a detailed outline of the requirements of plans that will be adherent to the IPMVP protocol.

Our goal with this document is to help members of the SkyFoundry community and other organizations that are evaluating software to assist in M&V projects to interpret IPMVP requirements and align those with SkySpark capabilities and feature sets.

Additional comments on the use of SkySpark to create final M&V reports follows on page 13 of this document.

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 and 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

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- or long-term metering. These data are normally considered to represent the independent variable(s) 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 (known as static factors) are assumed to remain constant. If they change, however, they may have to be addressed as part of non-routine adjustments. Examples of static conditions include:

- Occupancy type, occupancy density and run times.
- Operating conditions (e.g., set points, lighting and 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 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. In this case, the M&V agent should seek to 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.

4.1.5. Reporting Period

The reporting period is the 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 for longer, at periodic intervals such as a year, multiple years, or other time periods.

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In cases where the baseline and reporting periods are not of the same length, it is important to explain how the time frames are normalized so the baseline and reporting periods' 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 duration of the performance period.

4.1.6. 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 savings 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 adjustment determine whether savings are reported as avoided energy or as normalized savings.

Another 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 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.

4.1.7. 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.

4.1.8. 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 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.

4.1.9. Meter Specifications

The plan should specify the metering points that will be used to gather M&V data, including 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

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- Meter reading and witnessing protocol
- Meter commissioning procedure
- Calibration procedure/process
- Method of dealing with lost data and data transfer

4.1.10. 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 include:

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

4.1.11. 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.

4.1.12. Budget

The M&V plan should include the budget and the resources required for saving determination, as well as the costs for both the initial setup and ongoing tasks involved in evaluating, documenting and reporting the performance during each of the reporting periods.

4.1.13. 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 the M&V Reports* section *for details.*

4.1.14. 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.

4.2. Additional M&V Plan Requirements for Option A

4.2.1. Justification of Estimates

The M&V plan should clearly identify the variables to be estimated as part of the Option A 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.

4.2.2. 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.

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4.3. Additional M&V Plan Requirements for Option D

4.3.1. Software Identification

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

4.3.2. Input / Output Data

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

4.3.3. Measured Data

The M&V plan should describe the process of obtaining any measured data including which input parameters were measured and which ones 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.

4.3.4. 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.

4.3.5. 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.

4.4. M&V Reports

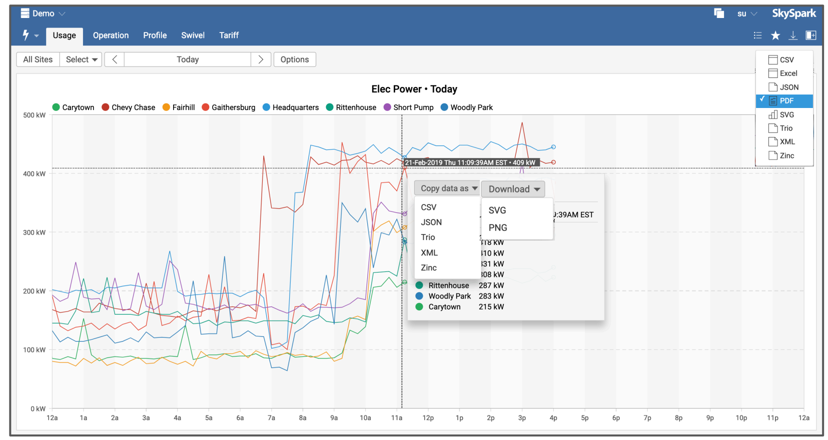
Periodic M&V reports are prepared as a means to document the overall performance of the measure and project using procedures outlined in the M&V plan. The frequency and the format for these M&V reports will also be included in the M&V plan. The report will include at a minimum the following information:

- 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 parameters of 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
  - Detailed description of data analysis and methodology
  - Updated list of assumptions and source of data used in the calculations
  - Details of any baseline or saving adjustments including both routine and non-routine adjustments to account for changes
  - Details of utility costs used to calculate the reported savings
  - Clear presentation of verified energy and cost savings and their comparison to the proposed savings

M & V Reports – The Final Step

SkySpark provides extensive features to assemble reports within SkySpark or to export graphic elements and data to be used in conventional documentation tools such as Microsoft Word® or Google Docs®. This provides M&V professionals with the flexibility to choose the tools that best fit their needs.

Views of charts, graphs, analytic findings (in fact, anything displayed by SkySpark) can be exported in formats including SVG, PNG and PDF. Data can be exported in formats including: CSV, JSON, XML, Zinc (and open source data format) and Trio (a SkySpark specific text format). See below for export options example.



In both cases (images and formatted reports), SkySpark can automatically generate documents and automatically email them to intended recipients, further eliminating manual effort.

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In Closing

SkyFoundry would again like to thank the Efficiency Valuation Organization for allowing us to use their materials on M&V and the IPVMP in this educational document.

We hope this document helps the reader interpret IPMVP requirements and align those with SkySpark capabilities and feature sets.

For additional information on SkySpark software contact SkyFoundry at:

https://skyfoundry.com/

Or email us at:

info@skyfoundry.com