المركز السعودي لكفاءة الطاقة
Saudi Energy Efficiency Center

ENERGY SAVING MEASUREMENT & VERIFICATION (M&V) USER GUIDE

For the Kingdom of Saudi Arabia

(Version #02)

January 2024

ACKNOWLEDGMENT

The Second version of the Energy Saving Measurement and Verification (M&V) User Guide was developed & updated by a team of local & international M&V experts in accordance with the Saudi Energy Efficiency Center (SEEC)'s framework to assure best practice of M&V methods and to become the norm in all areas of the ESPC program in the KSA.

Furthermore, this user guideline has been reviewed by the Efficiency Valuation Organization (EVO) to ensure the alignment with latest publications of International Performance Measurement and Verification Protocols (IPMVP).

The second version of the local user guideline has been developed based on the first version of this guideline, international M&V protocols and lessons learned from local energy efficiency projects.

SEEC would like to thank all the success partners from local ESCOs & M&V experts who provided their time, thoughts, and contributions during the process of updating the user guideline. Moreover, a special recognition to EVO who also provided valuable insights to local user guideline.

Table of Contents

Tables

Figures

ABBREVIATIONS AND ACRONYMS

KSA	Kingdom of Saudi Arabia
SEEC	Saudi Energy Efficiency Center
AEE	Association of Energy Engineers
DOE	Department of Energy (U.S.)
ESM	Energy Saving Measure
ENB	Energy Baselines
ENPI	Energy Performance Indicators
EPIA	Energy Performance Improvement Action
ESCO	Energy Service Company
ESM	Energy Saving Measure
ESPC	Energy Saving Performance Contract
EVO	Efficiency Valuation Organization
FEMP	Federal Energy Management Program
IPMVP	International Performance Measurement and Verification Protocol
ISO	International Standards Organization
M&V	Measurement and Verification
SMEs	Small and Medium-Sized Enterprises

DEFINITIONS OF KEY TERMS[1]

Adjusted Baseline Energy: The Baseline Period Energy Consumption modified as part of Routine and Non-Routine Adjustments to account for changes in conditions in the Reporting Period. Also called Adjusted Baseline Period Energy. Routine adjustments are used to account for expected variations in Independent Variables; Non-Routine adjustments are used to compensate for changes to documented baseline Static Factors.

Avoided Energy Consumption: Reduction in Energy Consumption, demand, or related cost that occurred relative to what measured energy (or demand) would have been without the Energy Saving Measure, most commonly determined under reporting period conditions. In some cases, avoided energy consumption may be determined under baseline conditions.

Baseline: Referring to (adjective) the systems, time period, energy use, or conditions that provide a reference to which later performance of an Energy Saving Measure (ESM) or measures can be compared.

Baseline Adjustments (BLA): See Non-Routine Adjustments.

Baseline Period: Defined period of time chosen to represent the operation of the facility or system before the implementation of Energy Saving Measure(s).

Baseline Period Energy: Energy Consumption and/or demand occurring during the Baseline Period without adjustments. Used to determine the energy that would have been used in the baseline period under the same operating conditions in the reporting period.

Commissioning: A quality-focused process for enhancing the delivery of a project and includes verifying and documenting that the facility and its systems and assemblies are planned, designed, installed, tested, operated and maintained to meet the design intent.

[1] Derived from various IPMVP Manuals

Confidence Level & Precision: Confidence level refers to the probability that the quoted range contains the true value. Precision is the measure of the range within which the true value is expected to occur with some specified level of confidence. Where estimated values are based on statistical results, the desired confidence level and precision are typically specified (e.g., 90/10, 80/20, 68/50), and the resulting precision is reported as either a range of values (absolute precision) or a percent of the estimated value (relative precision). These parameters represent the accuracy of a result.

Constant Value: A term used to describe a physical parameter that does not change during a period of interest. Minor variations may be observed in the parameter while still maintain describing it as constant. The magnitude of variations that are deemed to be 'minor' must be reported in the M&V Plan.

Degree Day: A degree day is a measure of the heating or cooling load on a facility created by outdoor temperature. When the mean daily outdoor temperature is one degree below a stated reference temperature such as 18^0C, for one day, it is defined that there is one heating degree day.

Demand: A measure of the rate at which work is done or energy is used when applied to a load. Electrical demand is normally expressed in kilowatts (kW).

Energy Consumption (Energy Use): Quantity of energy applied to any load in a specific period of time.

Energy Saving Measure (ESM): Action or set of actions designed to improve efficiency or reduce energy or manage demand. Sometimes referred to as an Energy Conservation Measure (ECM) or Energy Saving Measure (ESM). In this document the term is inclusive of water, greenhouse gases GHGs, energy storage, energy generation or another targeted project.

Energy Influencing Factor: Those operating conditions that can affect the energy use within a measurement boundary, including static factors and independent variables.

Energy Saving Performance Contract (ESPC or EPC): 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 Services Company (ESCO): A firm that provides services of design and construction of ESMs under an energy saving performance contract.

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 during the M&V period. The methods used to estimate values may range from engineering estimates derived from manufacturer ratings of equipment performance to measurements made during a different M&V period. 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.

Facility: A building or industrial site containing several energy using systems.

Greenhouse Gas Emissions: Greenhouse gases, including the carbon-containing gases carbon dioxide and methane, can be emitted through the burning of fossil fuels, and the production and consumption of network utilities and other products and services. Greenhouse gas (GHG) emissions caused by an individual, event, organization, service, place, or product, can be expressed as weight units of carbon dioxide equivalent and are sometimes referred to generically as carbon emissions.

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 Effects: Energy effects created by an ESM but not measured within the measurement boundary. Interactive effects may occur both within a single fuel source and between sources. For instance, a decrease in electrical energy for lighting may reduce electrical cooling load but also increase gas heating requirements.

Key Parameter(s): Critical variable(s) identified to have a significant impact on the energy saving associated with the installation of an Energy Saving Measure.

Measurement and Verification (M&V): Process of planning, measuring, collecting, and analyzing data for the purpose of verifying and reporting energy saving within a facility or facilities resulting from the implementation of ESMs. Saving commonly quantified include electricity consumption, electric demand, natural gas consumption, GHG emissions, water consumption, and may include utilities such as steam, energy generated, or any other item to be verified as part of a sustainability or efficiency project.

M&V Plan: A project-specific document detailing the methods, procedures, Analysis, and reporting that will be conducted in the baseline and reporting periods to verify and report saving.

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/or Demand of equipment or systems used within the boundary must be measured or estimated.

Metering: Devices used to collect energy consumption, demand data or key parameter data over time using measurements.

Non-Routine Adjustments (NRA): Individually engineered calculations to account for the energy effects within the Measurement Boundary due to changes in the Static Factors. When non-routine adjustments are applied to the baseline energy, they are sometimes just called “baseline adjustments” (BLAs).

Non-Routine Event (NRE): Unexpected changes in energy use within the measurement boundary resulting from changes in static factors, which are not accounted for in the energy saving calculations and not related to the targeted energy project.

Normalized Saving: The reduction in energy use or cost that occurred in the reporting period, relative to what would have occurred if the facility had been equipped and operated as it was in the baseline period but under a normal set of conditions. Normalization is using a statistically valid means of adjusting baseline and reporting period energy to a common set of conditions.

Operational Verification: Verification that the ESMs are installed and operating properly and have the potential to generate saving. Operational verification may involve inspections, functional performance testing, and/or data trending with analysis.

Performance Indicator: A measurable factor related to operating conditions which is used to assess the function of an ESM or system.

Proxy Measurement: A measured parameter substituted in place of direct measurement of energy consumption or demand, where a relationship between the two has been proven in situ, sometimes referred to as a validated proxy measurement. Example: If a relationship has been proven, via measurements between the output signal from a variable frequency drive controller and the power draw of the controlled fan, then the output signal may be used as a validated proxy measurement for fan motor power.

Regression Analysis: A mathematical technique that extracts parameters from a set of data to describe the correlation of measured independent variables and dependent variables (usually energy data).

Reporting Period: Defined period of time chosen for the purposes of verifying and quantifying saving after implementation of an Energy Saving Measure.

Reporting Period Energy: Energy Consumption and/or Demand used within a defined measurement boundary during the Reporting Period without adjustments.

Routine Adjustments: An adjustment to the baseline or reporting period data using mathematical and statistical methods to account for expected changes in energy consumption or demand due to changes in the Independent Variables affecting energy consumption within the Measurement Boundary.

Saving: Value, in quantifiable units, of energy consumption, water or demand reduction, or greenhouse gas emissions determined by comparing measured values before and after implementation of an Energy Saving Measure, making suitable Routine or Non-Routine Adjustments to account for changes in conditions. Energy or other unit saving and any resulting cost saving may be reported in the form of Energy Consumption or Normalized Saving.

Simulation Model: An assembly of algorithms that calculates energy use for a facility based on engineering equations and user-defined parameters.

Static Factors: Those characteristics of a facility which affect Energy Consumption and/or Demand, within the defined Measurement Boundary, that are not expected to change, and were therefore not included as Independent Variables. While not expected to change, these static factors should be recognized and monitored, and if they change, Non-routine Adjustments may need to be calculated to account for these changes. Note: Those characteristics may include fixed, environmental, operational and maintenance characteristics.

Verification: The process of examining a report prepared by others to comment on its suitability for the intended purpose.

Uncertainty in Saving: The range of saving values in which the true saving value is estimated to lie, often given a statistical confidence level. A single value does not adequately represent saving. Uncertainty in saving is reported either as a range of values (absolute uncertainty) or as a percent of the estimated saving (relative uncertainty).

EXECUTIVE SUMMARY

The Government of the Kingdom of Saudi Arabia (KSA) has recognized the high potential for energy efficiency improvement and has embarked upon a number of major energy efficiency initiatives. The KSA's interest in pursuing energy efficiency is driven by the potential financial and economic benefits at the fiscal and strategic levels. Hence, the Saudi Energy Efficiency Center (SEEC) was established to promote energy efficiency across the key sectors and unify the effort of government and non-government players in achieving the energy efficiency goals for KSA.

One of the important objectives of SEEC is the establishment of policies and programs to facilitate the implementation of energy Saving measures in buildings. To accomplish this objective, SEEC has deployed several initiatives to promote the development of a thriving Energy Services Companies (ESCO's) sector and the scale up demand-side energy efficiency implementation in buildings in the KSA using the energy saving performance contracting (ESPC) approach. A critical element for the successful implementation of ESPC for building energy efficiency requires the adoption, promotion and widespread utilization of a robust and practical measurement and verification (M&V) framework for assessing the resulting energy saving. SEEC therefore is establishing the methodologies, protocols, and plans for M&V and has prepared this M&V User Guide for the KSA.

In preparing the second version of the User Guide on M&V, SEEC drew from latest publications of IPMVP & lessons learned from KSA, in addition to the international experiences to develop and update a framework for conducting M&V. Local experience over the past 8 years & international experience have revealed that the practice of M&V typically involves the need for educated individuals guided by a set of principles, following common methods, and using consistent terminology.

Accordingly, all major M&V documents are guidelines, laying out general procedures to be adapted to each specific situation under consideration. In addition to general procedures, all guidelines emphasize the need for a site-specific M&V plan based on common terminology. Perhaps the most widely adopted international standard is the International Performance Measurement and Verification Protocol (IPMVP). This User

Guide draws frequently from the core concepts of M&V as defined in IPMVP.

While a common set of procedures and definitions, as set out in this User Guide, is a key element in the development of a robust M&V capability, it must be accompanied by the development of human resources to implement the M&V procedures. A community of individuals, at varying levels of responsibilities and capabilities depending on their job descriptions, must be developed to implement and review the M&V documents. Also, this community must be able to communicate frequently to share experience and build trust in the critical exercise of verifying energy efficiency saving.

This User Guide provides an overview of the framework that SEEC has developed to assure that Best Practice M&V methods become the norm in all areas of the ESPC program in the KSA, both within government projects and in the general economy. Through best practice quality M&V, the KSA can ensure the success of all performance-based EE programs.

SECTION 1: INTRODUCTION – MEASUREMENT AND VERIFICATION OF ENERGY SAVING

1.1 ENERGY EFFICIENCY IN THE KINGDOM OF SAUDI ARABIA

Kingdom of Saudi Arabia (KSA) s one of the world's leading oil producers and exporters. It has the second-largest proven crude oil reserves which made it one of the most significant players in the global oil market. Saudi Arabia also has a massive electricity distribution network that covers all major cities, towns, and villages across the country.

Recognizing the high potential for energy efficiency improvement, the Government of the KSA is now embarking upon several major energy efficiency initiatives.

The KSA's interest in pursuing energy efficiency is driven by the potential financial and economic benefits at the fiscal and strategic levels. The underlying rationale for investing public funds in promoting energy efficiency (EE) is based on the principles of cost-effectiveness. Specifically, increased energy efficiency can bring the following benefits to KSA:

- Free up millions of barrels of oil for export.

- Enhance national energy security.
- Improve reliability of electricity supply to consumers.
- Help avoid adding capital intensive power generation stations.
- Open up new employment opportunities.
- Generate more GHG emissions saving at lower investment cost than renewable energy.

Hence, the Saudi Energy Efficiency Center (SEEC) was established to promote energy efficiency across the key sectors and unify the effort of government and non-government players in achieving the energy efficiency goals for KSA.

One of the important objectives of SEEC is the establishment of policies and programs to facilitate the implementation of energy Saving measures in buildings. To accomplish this objective, SEEC has deployed several initiatives to promote the development of a thriving Energy Services Companies (ESCO's) sector and the scale up demand-side energy efficiency implementation in buildings in the KSA using the energy saving performance contracting (ESPC) approach.

The successful implementation of a financial incentive-driven energy saving performance contracting regime for implementing building energy Saving measures (in both the public and private sectors) requires the availability and use of a robust and practical framework for the measurement and verification (M&V) of the saving resulting from the building EE projects. The KSA therefore needs to establish the methodologies, protocols, and plans for measurement and verification of energy saving resulting from EE projects in public and private buildings.

The successful implementation of a financial incentive-driven energy saving performance contracting regime for implementing building energy saving measures (in both the public and private sectors) requires the availability and use of a robust and practical framework for the measurement and verification (M&V) of the saving resulting from the building EE projects. The KSA therefore needs to establish the methodologies, protocols, and plans for measurement and verification of energy saving resulting from EE projects in public and private buildings.

1.2 PURPOSE OF THIS USER GUIDE

International experience with implementation of EE projects in buildings (as well as in other sectors such as SMEs and large industry) demonstrates that the long-term success of energy saving projects has been hampered by the inability of project implementing partners (that is, building owners, ESCOs, and financiers) to agree on how the energy saving can be measured and verified to prove that the projects have been successful in meeting the expected results as laid out in the ESPCs. The development of internationally accepted methods and protocols for measurement and verification (M&V) of energy saving has facilitated the art, science and practice of M&V to support EE projects implemented using the ESPC approach.

This M&V User guide presents the guidelines and approaches, synthesized from the best available knowledge from international experience and practice of M&V. It presents procedures that, when implemented, allow building owners and managers, building operators, private ESCOs, and financial institutions who are likely to provide project financing for EE projects, to quantify the performance of an implemented Energy Saving Measure (ESM) by measuring and verifying the energy saving achieved by the ESM. Using the internationally accepted M&V protocol and guidelines presented in this User Guide allows various issues associated with achieving these saving to be identified vis-à-vis the risks and responsibilities allocated to the various parties engaged in the EE project.

International experience indicates that while building energy engineers and facility managers have monitored energy consumption in their facilities, there have been concerns about the accuracy and validity of many of the reported results. This User Guide provides the formal M&V protocol and practices to ensure that the reported energy and cost saving are valid and verifiable.

1.3 WHAT IS M&V?

"Measurement and Verification" (M&V) is the process of planning, measuring, collecting, and analyzing data to verify and report energy saving within a facility or facilities resulting from the implementation of ESMs. Saving commonly quantified include electricity consumption, electric demand, natural gas consumption, GHG emissions, water consumption, and may include utilities such as steam, energy generated, or other items to be verified as part of a sustainability or efficiency project process of using measurements to reliably determine saving of created within an individual facility through the application of ESMs. Saving cannot be directly measured since they represent the absence of energy consumption and/or demand. Instead, saving are determined by comparing measured consumption and/or demand before and after the implementation of a project, making appropriate adjustments for changes in conditions.

1.4 CONTEXT OF M&V

M&V is a fundamental part of many energy-focused efforts such as those involving:

- Energy performance contractors and their customers.
- Utility demand-side management program designers, managers, and evaluators.
- Energy users implementing ESMs and wanting to quantify saving.
- Facility managers properly accounting for energy budget variances.
- Existing building managers seeking recognition for the environmental quality of their facility operations.
- New building designers wishing to account for the sustainability of their designs.
- Water efficiency project developers.
- Emission reduction trading program designers.
- Energy users seeking ISO 50001 certification.

Financial backers, project managers, and implementors of the above applications will find a use of this document to establish a shared framework and ensure key elements are addressed.

1.5 PURPOSES OF M&V

Table 1 PURPOSES OF M&V

M&V Purposes	Applications
Manage Project-Related Risks	An M&V Plan is a risk mitigation tool used when implementing energy efficiency projects. A carefully crafted M&V Plan can manage project risks for the parties involved while ensuring performance goals are met. Balancing risks requires stakeholders to fully understand the potential impacts from variations in financial, operational, and performance-related parameters.
Provide Feedback on ESM Efficacy	Accurate determination of realized energy saving provides facility owners and managers valuable feedback on their energy saving measures (ESMs). This feedback helps them adjust ESM design or operations to improve saving and achieve greater persistence of saving over time.
Document Financial Transactions	For some projects, energy efficiency saving form the basis for saving-based financial payments and/or a guarantee in a performance contract. A well-defined and implemented M&V Plan serves as the basis for documenting performance in a transparent manner. The M&V Plan and Reports should be subject to independent verification.
Enable Financing for Efficiency Projects	A good M&V Plan increases the transparency and credibility of reports regarding the outcome of efficiency investments. It also increases the credibility of projections for the outcome of these efficiency investments. This credibility can increase the confidence that investors and sponsors have in energy efficiency projects, enhancing their chances of being financed.

M&V Purposes	Applications
Improve Engineering Design and Facility Operations and Maintenance	The preparation of a good M&V Plan encourages comprehensive project design by including all M&V costs in the project's economics. Good M&V also helps managers discover and reduce maintenance and operating problems so that facilities can be run more effectively. Good M&V also provides feedback for future project designs.
Manage Energy Budgets	Even where saving are not planned, M&V techniques help managers evaluate and manage energy consumption and demand to account for variances from budgets. M&V techniques are used to adjust for changing facility-operating conditions to set proper budgets and account for budget variances.
Validate Emission Reduction Outcomes	Verifiable quantification of GHG emission reductions provides additional value to efficiency projects and greater benefit recognition for sustainability efforts.
Support Evaluation of Efficiency Programs	Utility- or government-sponsored programs for managing the use of an energy supply system can use M&V techniques to estimate the saving at specific energy user facilities. Using statistical techniques and other assumptions, the saving determined by M&V activities at selected individual facilities can be used at unmeasured sites to evaluate the performance of the entire program.

1.6 Outline of this User Guide

This Guide provides information for all parties involved in or benefiting from measuring and verifying the results of energy saving projects. It is useful for:

- ESCOs and other ESPs when planning and implementing M&V for their projects.
- Facility owners and managers need to satisfy themselves with the soundness of the M&V for their project and evaluate the M&V results reported by ESCOs and ESPs.

- Government agencies in planning and reporting energy saving and greenhouse gas reductions.
- Anyone who is involved in the quantification and verification of reductions in GHG emissions resulting from the EE project.
- Governments are interested in providing reliable and credible information to energy users regarding the benefits of energy saving projects.

Section 2: of this User Guide presents an overview of the core concepts of M&V, summarizes some of the M&V methodologies and protocols used internationally, and provides an overview of the International Performance Measurement and Verification Protocol (IPMVP). The section provides a summary of the fundamental principles of M&V and describes the major steps in conducting M&V. In addition, this section provides a discussion of the M&V planning process and describes the major steps in this process. It also includes a discussion of the baseline upon which the energy saving calculations are based. Next, it provides a discussion of issues related to metering equipment and systems. Finally, it discusses the need to monitor static factors and methodology of deriving non-routine adjustments.

Section 3: of the User Guide focuses on the M&V framework and the four major M&V options. It presents the basic equations of M&V and key elements of the M&V framework. The section then provides a detailed discussion of the four M&V Options:

- Option A: Retrofit Isolation – Key Parameter(s) Measurement
- Option B: Retrofit Isolation – All Parameter Measurement
- Option C: Whole Facility Analysis
- Option D: Calibrated Simulation

Section 4: presents the contents of M&V Plan. An IPMVP adherent M&V Plan is one that meets all the 15 criteria and a checklist for the same is attached in Annex.

Section 5: presents the contents of M&V Saving Report. It lists the information that should be provided for the sake of transparency, accuracy, and reliability.

Section 6: discusses how M&V can be done for Renewable Energy Technologies

Annexes: provides an M&V Plan Template, Regression based Energy Models, M&V Plan checklist, Sampling for M&V and Instrumentation & Modeling for Retrofit Isolation.

SECTION 2 - OVERVIEW OF CORE CONCEPTS, PROTOCOLS AND GUIDELINES FOR M&V

2.1 BASIC M&V CONCEPT

2.2.1 Background

SEEC seeks to develop a general measurement and verification (M&V) capability within the Kingdom of Saudi Arabia to support the development of the ESCO industry and ESPC market in general, and to facilitate the operations of the sector, particularly in the buildings EE sector. With respect to methodologies, the simplest is the deemed or stipulated saving approach, under which the participants agree to the unit energy saving and the operational utilization factors for the retrofit measures and use simple formulas to calculate the energy saving. However, this approach may not be suitable for more complex retrofits (such as whole building retrofits) where more formal M&V methodologies may be necessary.

For more formal M&V, a number of approaches are available. The most common and widely accepted set of approaches are detailed in the International Performance Measurement and Verification Protocol (IPMVP), which provides an overview of current best practice techniques available for verifying results of energy efficiency in buildings and industrial facilities. Although IPMVP originated in the US, it is now applied globally, and many countries have adopted IPMVP or its core principles in developing their own M&V Protocols and plans.

2.1.2 Overview of the International Performance Measurement and Verification Protocol (IPMVP)

The International Performance Measurement and Verification Protocol (IPMVP) was developed in the U.S. by a coalition of researchers and practitioners to provide a flexible framework of M&V options that allows practitioners to craft the best M&V plans for their projects. IPMVP was originally developed in 1996 (as the North American Energy Measurement and Verification Protocol, renamed as IPMVP in 1997) and has undergone several modifications and improvements over the years. Its development and management is now under an independent organization, Efficiency Valuation Organization[2] (EVO) which is dedicated to creating tools and training individuals to quantify the results of EE projects and programs.

2.1.3 IPMVP as the Generally Accepted M&V Protocol

IPMVP has now become the most widely accepted M&V protocol worldwide and represents the starting point for almost all global activity in M&V. It is currently being used in over 20 countries either as the framework specified by Efficiency Valuation Organization (EVO) or with an adaptation of IPMVP customized to the local needs.

Around the world, the ESCO industry has adopted IPMVP as the common framework for defining Measurement and Verification operations. The strengths of IPMVP are:

- It was developed by a group of experts with substantial experience in EE programs.
- It was developed as a high-level tool to provide maximum flexibility to its users while maintaining strict requirements for transparency and efficacy of application.
- It provides four different options that address the wide range of EE retrofit measures and their characteristics with respect to measurement of energy and cost saving.
- It has a management and support structure through EVO that provides technical assistance and services to users.
- It can be easily adapted by users to a wide range of different types of projects.
- It provides international credibility for energy saving reports, thereby increasing the value to a beneficiary or purchaser of the associated energy

[2] EVO is responsible for the management, support and training related to the use of IPMVP for conducting M&V.

saving.

- It benefits from the active participation of a worldwide network of volunteers who provide updates on the latest application of methods.

Each adopting organization of IPMVP typically brings unique requirements for how IPMVP may best be applied in each context. Perhaps the best example of this is the Federal Energy Management Program (FEMP) M&V Guidelines. The FEMP Guidelines were developed simultaneously with the IPMVP (and by mostly the same individuals) with the goal of providing specific guidance on how to apply IPMVP within U.S. Federal contracts. One of the important advantages of IPMVP is that it has a structure in place to modify and improve the protocol and associated methodologies as new requirements emerge.

2.2 PRINCIPLES OF M&V[3]

The fundamental principles of M&V, as described by IPMVP, are described below.

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 saving being evaluated. M&V expenditure 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 assumptions based on sound engineering judgment. Consideration of all reasonable factors that affect accuracy is a guiding principle of IPMVP.

COMPLETE

The reporting of energy saving should consider all effects of a project. M&V activities should use measurements to quantify energy use within the measurement

[3] Source: International Performance Measurement and Verification Protocol: Core Concepts, EVO 10000 – 1:2022, March 2022.

boundary, document energy influencing factors, and detail any estimated values.

Conservative

Where judgments are made about uncertain quantities, M&V procedures should be designed to reasonably estimate saving 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 statistical 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.

Consistent does not mean identical, since it is recognized that any empirically derived report involves assumptions based on sound engineering judgment which may not be made identically by all reporters. By identifying key areas where judgment is required, IPMVP helps to avoid inconsistencies arising from lack of consideration of important aspects.

Relevant

The determination of saving should be based on current measurements and information pertaining to the facility where the project occurs. This determination of the saving effort must measure the energy influencing factors and verify performance indicators that are of concern related to the ESM.

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 best 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 saving reporting procedures.

2.3 M&V PROCESS – ESCO, CLIENT AND 3RD PARTY M&V AGENT

Where an ESCO is selected by a facility owner to make and report energy saving, the owner may involve a 3rd party M&V agent to review the saving reports. The inclusion of a third-party reviewer is part of conducting quality assurance activities. This 3rd party M&V agent should begin by reviewing the M&V Plan during its preparation, to ensure that the saving reports will satisfy the owner's expectations for rigor in saving and mitigation of risks.

A 3rd party M&V agent may be helpful to ensure measurement validity and to prevent conflicts. If conflicts arise during the reporting period, this 3rd party M&V agent can help to resolve the conflicts. 3rd party M&V agents are typically engineering consultants with experience and knowledge in ESMs, M&V, and energy performance contracting.

When payments are contingent on proven performance, third-party verification should be required. This role should be stipulated in the contractual agreement. Additionally, consideration should be given in the contract to the circumstance where verification by the third party reveals unsatisfactory elements to the M&V Plan or Saving Reporting. The third-party review should be conducted by a reviewer that is wholly independent of the M&V Plan author (and their organization).

During an independent review, in addition to field verification of the installation, the reviewer should conduct activities needed to observe that the ESM is based on sound scientific principles and that independent evidence exists to support any claims made regarding its efficacy.

Adherence with User Guide means the M&V process is implemented to assure saving are determined as per internationally recognized best practices. The M&V process is illustrated in below Figure (1) and described by the following steps:

1. The project's energy saving estimates and the scope of the ESMs are evaluated to help select appropriate M&V Options and strategies, and to evaluate the level of effort and costs required for the M&V process.
2. Develop an M&V Plan that ensures the project uses the IPMVP's Framework, Principles, and adequately applies the IPMVP Option(s).
3. Develop a complete M&V Plan as described in Section (4), which:

- Defines the IPMVP Option(s) used and follows the requirements for that/those Option(s) detailed in Section (3).
- Includes all information presented in Section (4) – M&V Plan
- Defines the contents of saving reports and the frequency and duration that saving will be reported.
- Is consistent with the Principles of IPMVP.

4. The M&V Plan is reviewed for adherence to IPMVP Options, procedures, and principles. The review may be performed by a qualified third party.
5. The Final M&V Plan is reviewed and approved by all stakeholders. Project stakeholders must understand and agree upon the M&V Plan for a project.
6. Identify the person(s) responsible for executing the site-specific M&V Plan and for making sure that the M&V Plan is followed during the Reporting Period(s).
7. Implement the agreed-upon M&V Plan and ensure its procedures are followed. 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.
8. The Saving Reports are developed per the M&V Plan and include all content specified in Section (5).

9. The Saving Reports are reviewed for adherence with the M&V Plan and IPMVP methods, procedures, and principles. The review may be performed by a qualified third party.

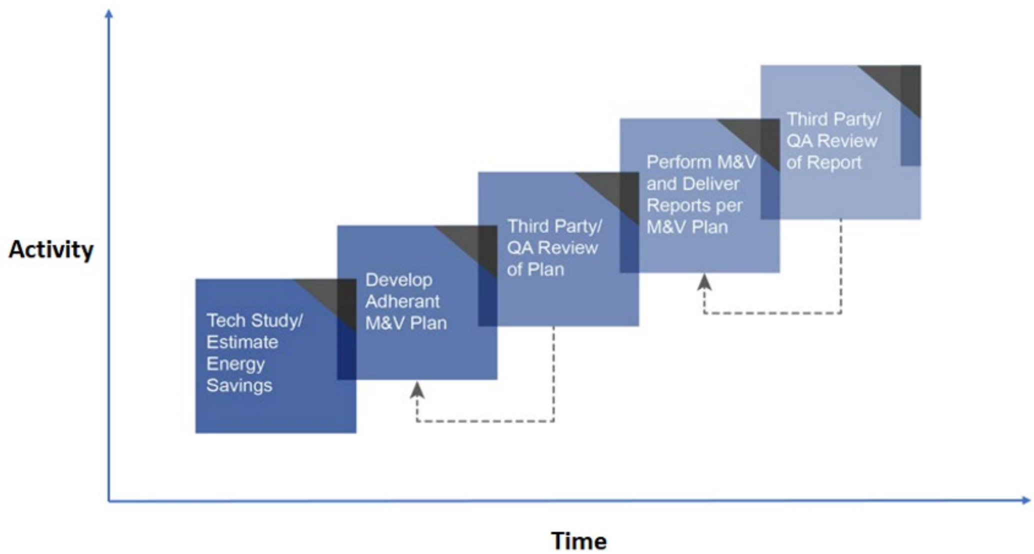


Figure 1 Flowchart of M&V Process with Typical Adherence Activities[4]

2.4 OTHER M&V GUIDELINES

2.4.1 IPMVP Protocol & Other M&V Guidelines

The IPMVP is a protocol which establishes a construct for verifying saving using the M&V process. It is the intent of the IPMVP that other industry publications be used in conjunction with this document to provide additional guidelines for specific applications. There are many M&V guidelines based on the IPMVP, including:

→ M&V Guidelines: Measurement & Verification for Performance Based Contracts, Version 4.0, U.S. Department of Energy Federal Energy Management Program (FEMP)

→ ASHRAE Guideline 14-2014: Measurement of Energy and Demand Saving

[4] Source: IPMVP Core Concepts (October 2016, EVO 10000-1:2016)

→ ISO 17741: 2016 General Technical Rules for Measurement, Calculation and Verification of Energy Saving of Projects

Some newer protocols for specific applications such as greenhouse gas emissions have largely duplicated IPMVP's construct and terminology, with some variations and the addition of application specific considerations. It is important to note that projects implemented under these applications should largely adhere to IPMVP's principles and process.

2.4.2 ISO 50001:2018 – Energy Management System[5]

ISO 50001 is based on the management system model of continual improvement also used for other well-known standards such as ISO 9001 or ISO 14001. This makes it easier for organizations to integrate energy management into their overall efforts to improve quality and environmental management.

ISO 50001:2018 provides a framework of requirements for organizations to:

- Develop a policy for more efficient use of energy.
- Fix targets and objectives to meet the policy.
- Use data to better understand and make decisions about energy use.
- Measure the results.
- Review how well the policy works, and continually improve energy management.

Two standards released in 2014 support implementation of ISO 50001.

- ISO 50006:2014, Energy management systems -- Measuring energy performance using energy baselines (EnB) and energy performance indicators (EnPI) -- General principles and guidance provides practical guidance on how to meet the requirements of ISO 50001, and therefore manage their energy performance.
- ISO 50015:2014, Energy management systems -- Measurement and verification of energy performance of organizations -- General principles

[5] From the ISO web site

http://www.iso.org/iso/home/standards/management-standards/iso50001.html and guidance provides a set of principles and guidelines for Measurement and Verification, thereby increasing the credibility of energy performance.

The fundamental concepts included in the ISO series of standards are materially aligned with IPMVP. However, because 50001 focuses on overall performance of energy system – energy inputs AND organization outputs – it adopts different terminology for similar concepts. For example, the IPMVP defines energy saving projects as “energy saving measures” or ESMs. In the ISO documents, the energy project is called an “Energy Management Action Plan”, or EMAP[6].

2.5 M&V PLANNING

2.5.1 Importance of the M&V Plan

Because ESCO contracts are performance-based, appropriate protocols need to be developed and agreed on regarding how energy saving will be measured and verified so payments can be made to the ESCO. The M&V plan is a document that defines project-specific M&V procedures and methods for determining verified energy saving. The M&V Plan is central to proper verified saving determination and is the basis of verification. The plan is essential to ensure the transparency of processes and the quality and credibility of achieved outcomes.

A good M&V plan ensures that all the needed data and computational processes will be available for the saving determination within an acceptable budget. An important objective of the M&V plan is to arrive at a balance between cost and accuracy.

2.5.2 Typical Contents of a M&V Plan

The objectives, design, and constraints of the project and the proposed ESMs have a major influence on the structure and contents of the M&V Plan, as do the facility’s major energy equipment and usage patterns. The amount of variation in energy use patterns and the estimated impact of the ESMs help to establish the amount of effort needed to determine saving. Generally, variable loads or operating hours require more rigorous measurement and computation processes. Such issues will affect

6 EVO has developed an online training course on “ISO 50015 and the IPMVP”.

the amount of effort required in collecting the data and in performing the computations.

While the specific elements of the M&V plan will depend on the nature of the project and individual ESMs, the M&V plan should generally include the following:

- Description of energy saving measures and their intended results.
- Definition of the M&V objectives and constraints consistent with the energy saving project objectives and constraints.
- Identification of the measurement boundary and the M&V option to be utilized.
- Operational verification procedures that will be used to verify successful implementation of each ESM.
- Documentation of the baseline conditions (facility characteristics, equipment data, operational considerations, and energy consumption data).
- Definition of the responsibilities for the monitoring of the energy use data and baseline conditions.
- Specification of measurement equipment, measurement points, measurement period (pre- and post-installation) and measurement analysis.
- Identification of any planned changes in the building characteristics or operations.
- Definition of analytical procedures and models to be used.
- Identification of the post-installation period conditions.
- Specification of analysis procedures, algorithms, and assumptions.
- Specification of software, budget, and resource needs.
- Specification of the energy prices to be used for calculating cost saving.
- Specification of the accuracy and uncertainty in the saving estimates and quality assurance procedures to minimize the risk.
- Methods for making relevant baseline adjustments.
- Reporting format for the M&V results.

This is covered in detail in Section (4) & (5).

2.5.3 Baseline Adjustments

An important element in the M&V process is the definition of the baseline, which specifies the pre-implementation conditions against which the saving (or other specified performance parameters) are measured. During the term of the ESPC, non-routine changes in the reporting period may occur that could affect the level of energy saving or performance. Such changes may include:

- Changes in facility use or operating conditions.
- Changes in occupancy.
- Changes in equipment operating schedules.
- Changes in indoor environmental conditions (such as thermostat settings).
- Changes in outdoor environmental conditions (solar shading, etc).
- Additions of new energy-using equipment.
- Facility refurbishment or rehabilitation.

It is important to include in the M&V plan specific provisions regarding what changes would require adjusting the baseline, how such changes will be identified and tracked, and how the baseline should be modified in case such changes occur. Additional details on baseline adjustments for each of the four M&V options are provided in Section (3).

2.5.4 Key Steps in M&V Process[7]

The next table illustrates the key steps in M&V process.

Table 2 Key Steps in M&V Process

Project Stage	Steps
Baseline Period	Step 1: Determine Goals for M&V Efforts
	Step 2: Select IPMVP Option(s) and Approaches
	Step 3: Document Baseline Data
	Step 4: Develop M&V Plan
	Step 5: Set-up Metering and Ongoing Data Collection Processes
Installation Period	Step 6: Monitor for Changes in Site Conditions
	Step 7: Confirm Operational Verification
Reporting Period	Step 8: Ongoing Data Collection
	Step 9: Determine Saving for Period
	Step 10: M&V Report for Period
	Step 11: Track Energy Performance and Saving

The previous steps are described as follows:

Step 1 – Determine Goals for M&V Efforts.

Consider the needs of the stakeholders using the planned M&V Report(s). Evaluate project risks and identify the goals of the M&V effort. If the stakeholders are focused on overall cost control, Whole Facility methods may be best suited. If the focus is on the performance of particular ESMs, Retrofit Isolation techniques may be best suited.

[7] Source: IPMVP Core Concepts 2022 – EVO 10000-1 :2011 (March 2022), Chapter 5.

Step 2 – Select IPMVP Option(s) and Approaches.

While developing the ESM(s), select the IPMVP Option(s) and define the measurement boundary that best suits the ESM(s) or overall project, the needs for accuracy and granularity in verified saving, the level of saving expected, and the budget for M&V. A combination of M&V Options may be best suited to some projects.

Decide whether adjustments of all energy quantities will be made to reporting period conditions or to some other meaningful set of conditions. Agree on the duration of the baseline period and the reporting period(s). These fundamental decisions will be written into the M&V Plan for the project.

Step 3 – Document Baseline Data.

Assess the planned ESMs and the energy influencing factors. Collect relevant energy and operating data from the baseline period and record them in a way that can be accessed in the future and includes relevant details, as outlined in M&V Plan.

Step 4 – Develop M&V Plan.

Prepare an M&V Plan detailing the results of Steps 1 through 3 and addressing all the criteria as specified M&V Plan. It should define the subsequent Steps 5 through 11. Assess baseline energy, independent variables, and metering. Consider rigor in saving required. Establish any models that will be used to make planned adjustments to the baseline energy. Define energy calculations, provide a rationale(s) for the approaches used, define the expected level of effort or budget.

The final M&V Plan must be understood and approved by all stakeholders (e.g., owner/project sponsor and project developer/M&V agent) and may be adopted as terms and conditions for an energy performance contract or other agreement.

Step 5 – Set Up Metering and Ongoing Data Collection Processes.

As part of the final ESM design and installation, also design, install, calibrate, and commission any special measurement equipment that is needed under the M&V

Plan.

Step 6 – Monitor for Changes in Site Conditions.

During the ESM installation period, monitor for changes in conditions (i.e., static factors) at the site that could impact saving.

Step 7 – Confirm Operational Verification

After the ESM is installed, ensure it has the potential to perform and achieve saving by confirming appropriate operational verification is conducted as required by the project, which may include various methods from inspection and simple measurements to a full commissioning process depending on the complexity and saving of the ESM. Operational verification is conducted by the installing party and may be overseen by a third party such as a commissioning agent.

Step 8 – Ongoing Data Collection

Gather energy, operating data and details of other energy influencing factors from the reporting period, as defined in the M&V Plan.

Step 9 – Determine Saving for the Period

Compute saving in energy and monetary units in accordance with the M&V Plan.

Step 10 – M&V Report for the Period

Report verified saving in accordance with the M&V Plan. Submit saving report to stakeholders after third-party review.

Step 11 – Track Energy Performance and Saving

Repeat Steps 8 through 11 throughout the M&V reporting period(s), as defined by the M&V Plan. A third party may be engaged to verify that the M&V Plan adheres to the IPMVP and possibly contract terms. This third party should also verify that saving reports comply with the approved M&V Plan.

Verification of saving can be performed by an independent party or by the project developer as long as quality assurance oversight is performed by a qualified person (such as a PMVA, a PMVE, or CMVP®).

2.6 DEFINING THE BASELINE

2.6.1 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 span a full operating cycle from maximum energy consumption and demand to minimum.
- Include only time periods for which factors that impact energy use are known about the facility.

→ Note: The extension of baseline periods backwards in time to include multiple cycles of operation requires equal knowledge of factors that impact energy use throughout the longer baseline period, to properly derive routine and non-routine adjustments after ESM installation.

- Coincide with the period immediately before implementing the energy saving measures.

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

- Support ESM planning.

ESM 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 operating cycle length.

2.6.2 Baseline Period Conditions

The baseline conditions must be well-documented because they represent a critical element of the M&V process and becomes unavailable once the ESM(s) is (are) implemented.

Data representing Greenhouse Gas Emissions need to be documented corresponding to the time period for which energy consumption data are collected. Data related to the ESM(s), independent variables, and static factors are needed. The extent of the information required is determined by the selected M&V Option, measurement boundary chosen, and the energy influencing factors.

This may include variables such as production data, ambient temperature, equipment or system operating pressures or other variables collected through spot measurements, short-term or long-term metering or site-inspections.

The prevailing conditions (also known as static factors) are normally assumed to remain constant over both the baseline, installation, and reporting periods. If static factors change and the impact to saving is substantial, then this will have to be addressed as part of non-routine adjustments. Examples of static factors are varied and may include:

- Occupancy type, occupancy density and equipment run times.
- Operating conditions (e.g., set points, lighting levels, ventilation levels) for each operational mode and season during the baseline period.

It is also important to identify planned changes to conditions that may affect the reporting period energy. Planned changes may include any number of items such as increase in occupancy levels, adding a shift, changing size of facility served, or increasing lighting levels.

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.

- Significant equipment problems or outages, facility shutdowns, or atypical operations during the baseline period.
- Adjustments to the baseline could 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.

2.7 Issues Related to Metering Equipment and Systems

2.7.1 Utility Metering Issues

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

Separate meters installed by the facility owner can measure whole facility energy consumption or energy consumption for a portion of the facility. 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. If meters are read on separate days, then each meter having a unique billing period should be separately analyzed. The resultant saving can be combined after analysis of each individual meter if the dates are reported.

2.7.2 Energy Sub-Metering Issues

It is important to follow good measurement practices to enable calculation of energy saving with reasonable accuracy and repeatability. Measurement practices are continually evolving as metering equipment improves. Therefore, use the current best practices in measurement instrumentation and data management to support determining the saving. Where meters are used for additional business value, it may be possible for those business functions to bear some of the metering costs.

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 saving are not to be determined, can be ignored. Determine saving 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.

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 as defined in the M&V plan. However, the reported saving for the missing period should identify these saving as missing data. and a source of uncertainty in saving.

2.7.3 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. Saving reports should note when estimates are part of the utility data. Recorded energy use values that are known to be estimates should not be included in the baseline energy.

2.7.4 Solid / Liquid Fuel Consumption

Energy consumption can either be metered directly (electricity, gas) or measured by some other means (e.g., weight or volume of wood pellets, wood chips, manure, etc.).

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.

2.7.5 Retrofit Isolation Measurements

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 ESM. Alternatively, meters may be installed to measure baseline performance for an M&V Plan.

Key parameters may be continuously measured or periodically measured for short periods. The expected amount of variation in a specific 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 ESM installation and checked occasionally throughout the reporting period. The frequency of this checking can be determined by beginning with measurements sufficient 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 saving 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 ESM performance but is not performing ESM operation and maintenance, the length of measurements in the reporting period may be limited. For subsequent periods where re-inspections are used rather than measurements to validate the value of a key parameter, the reported energy saving are not IPMVP adherent.

Continuous metering provides greater certainty in reported saving 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 ESM 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 meter's accuracy and the procedure for calibrating the meter being used.

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. These measurements are often used to make routine adjustments.

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

Temporary meters may be used if only short-term metering is needed. Although the costs of portable meters can be lower, 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.

To measure electricity accurately, measure the voltage, amperage, and power factor, or true Root Mean Squared (RMS) wattage with a single instrument. RMS power meters and data loggers should be used wherever possible. RMS measurements account for normally occurring distortions in alternating current as well as changes in power factor.

Meters should be calibrated as recommended by the equipment manufacturer and following the procedures of recognized measurement authorities. Primary standards and 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.

2.7.6 Data Collection Issues

No data collection process is without error. Methodologies for reporting period data collection differ in degree of difficulty, and consequently in the amount of erroneous or missing data that may arise. The M&V Plan should establish a maximum acceptable rate of data loss and how it will be measured. This level should be part of the overall accuracy consideration. The level of data loss may dramatically affect cost. The M&V Plan should also establish a methodology by which missing or erroneous reporting period data will be re-created by interpolation for final analysis. In such cases, reporting-period models are needed to interpolate between the measured data points so that saving can be calculated for each period.

Note that baseline data consist of real facts about energy and independent variables as they existed during the baseline period. Therefore, baseline data problems should not be replaced by modeled data, except when using Option D. Where baseline data are missing or inadequate, seek other real data to substitute, or change the baseline period so that it contains only real data. The M&V Plan should document the source of all baseline data.

2.7.7 Use of BMS for Data Collection

Many facilities have computerized systems to monitor or control a facility's equipment or processes. These are commonly referred to as building management systems (BMS) and can provide much of the monitoring and data collection for some

M&V efforts. However, the system's hardware and software must be capable of performing the intended monitoring control and data gathering simultaneously, without slowing computer processing, consuming excess communication bandwidth, or overfilling storage. The frequency of the data recorded as well as data communication and management methods should also be considered.

Control system software can often perform other functions to assist the tracking of changes to static factors during the reporting period, such as automatically recording changes in setpoints or other energy governing factor. Control systems can record energy consumption from sub-meters on various equipment or systems.

Great care should be exercised to:

- → Control access and/or changes to the system's trend log from which the energy or key parameter data are extracted.
- → Develop post-processing routines for changing any control-system COV (change of value) data into time-series data for performing the analysis.
- → Validate sub-meters are appropriate for the application, properly located, mapped, and calibrated. Get from the system supplier:
- Standard traceable calibrations of all meters and sensors used,
- Evidence that proprietary algorithms for counting and/or totaling pulses and units are accurate, and the commitment that there are adequate processing and storage capacity to handle trending data while supporting the system's control functions.

2.8 NON-ROUTINE ADJUSTMENTS (NRAs)[8]

Conditions, which vary in a predictable fashion and are significant to energy consumption and/or demand within the measurement boundary are normally included within the mathematical model used for routine adjustments. Where unexpected changes occur in conditions (including atypical operations) which are

[8] Source – IPMVP Application Guide on NRE & NRA Oct-2020

otherwise static (static factors) affecting energy use within the measurement boundary, non-routine adjustments must be made, as indicated in the IPMVP saving equations.

Examples of static factors requiring non-routine adjustments are changes in the:

- → Amount of space being heated or air conditioned.
- → Type of products being produced or number of production shifts per day.
- → Building envelope characteristics (new insulation, windows, doors, air tightness).
- → Amount, type or use of the facility's and the users' equipment.
- → Indoor environmental standard (e.g., light levels, temperature, ventilation rate).
- → Occupancy type or schedule.

Baseline conditions need to be fully documented in the M&V Plan so that changes in static factors can be identified and proper non-routine adjustments made. It is important to have a method of tracking and reporting changes in these same static factors. This tracking of conditions may be performed by one or more of the facility owners, the agent creating saving, or a third-party verifier. It should be established in the M&V Plan who will track and report each static factor. Where the nature of future changes can be anticipated, methods for making the relevant non-routine adjustments should be included in the M&V Plan.

Non-routine Events (NREs) are unexpected changes in energy use within the measurement boundary resulting from changes in static factors, which are not accounted for in the energy saving calculations and not related to the targeted energy project. NREs can include a broad array of temporary or permanent site changes. Variations in occupancy densities, facility run times, system operating parameters (e.g., set points, lighting levels, production rates, equipment staging, etc) and new equipment installed may be NREs.

When an energy consumption change is unrelated to the energy project and is due to change in static factors, then it would be considered an NRE. If the impact from the NRE on saving is significant enough, then a non-routine adjustment is required.

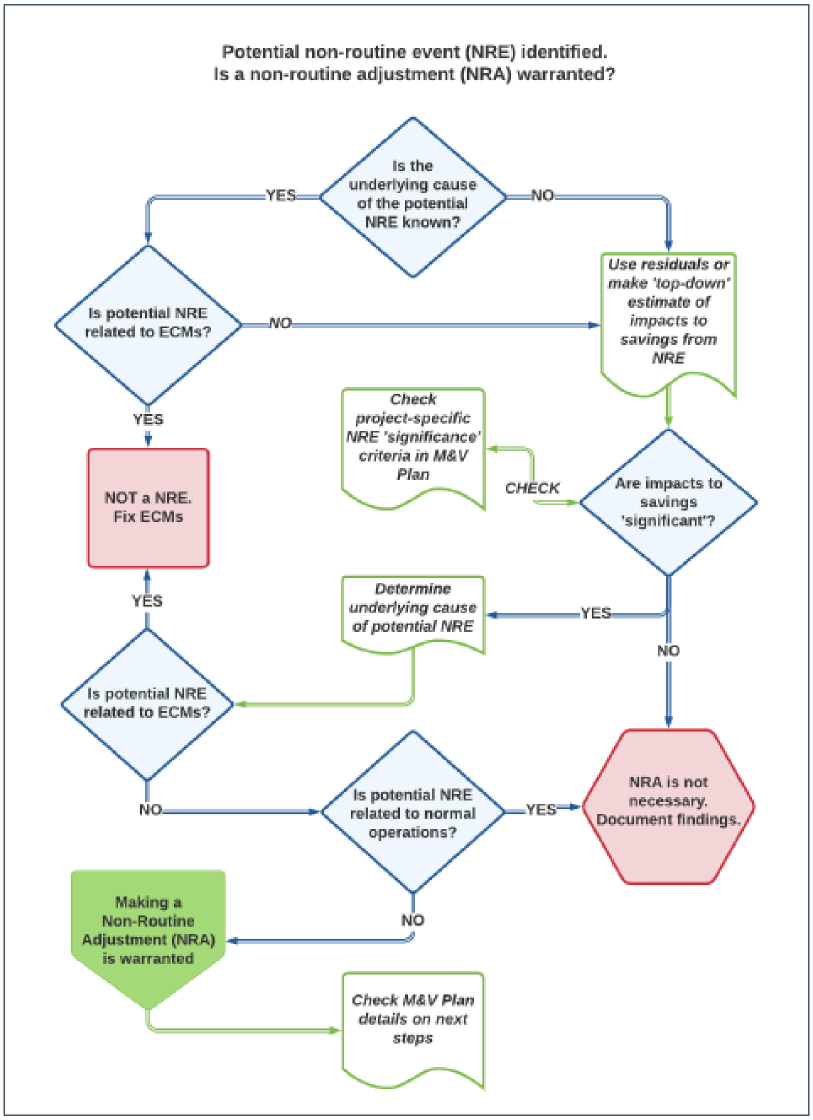


Figure 2 Flowchart for Assessing Potential NREs

In general, the original IPMVP Option (A, B, C or D) used in a project is the preferred approach to make an NRA. If possible, the methods used to estimate an ESM's energy saving should be used to value an associated NRA and include similar measurement and calculation techniques. This ensures the NRA is consistent with the calculated saving, maintaining uniformity in the saving estimate.

Selecting an NRA method may require trade-offs between accuracy and level of effort (or costs). The NRA methods, in general order of preference, are to:

→ Omit data (NRA Method #1) or use sub-metered energy data (NRA Method #2)

→ Redefine the baseline Model (NRA Method #3)

→ Use a regression-based method (NRA Methods #4-8)

→ Use a calibrated building simulation model (NRA Method #9)

→ Use engineering calculations (NRA Method #10)

Below table summarizes the various NRA methods from IPMVP:

#	Project Period	Baseline		Implementation		Reporting		Basis of Adjustment	
	Duration of NRE / NRA Method	Temporary	Permanent	Temporary	Permanent	Temporary	Permanent	Avoided Energy Consumption	Normalized Energy Savings
1	Omit Data	X				X		X	X
2	Use Sub-Metered Energy Use	X	X		X	X	X	X	X
3	Redefine Baseline Model Using New Variables	X	X		X	X	X	X	X
4	Use Model Residuals from the NRE Period					X	X	X	X
5	Create an 'NRE Adjustment Model'					X		X	
6	Use 'Mini' Models					X	X	X	X
7	Develop a 'Pre-Post NRE' Model					X	X	X	X
8	Adjust for Significant Trends in Residuals						X	X	X
9	Use Calibrated Simulation	X	X		X	X	X	X	X
10	Use Engineering Calculations*		X		X	X	X	X	X
#	Alternate M&V Approaches								
1	Use Backcasting							X	
2	Apply Chaining							X	
3	Use a New M&V Option	X	X		X	X	X	X	X

Figure 3 NRA Methods[9]

Preferably, measurements should be used to quantify impacts of non-routine adjustments (NRA Method #2).

[9] Source – IPMVP Application Guide on NRE & NRA Oct-2020

Sometimes it may be difficult to quantify the impact of changes, for example, if they are numerous or not well documented. It is recommended to refer to IPMVP Application Guide on Non-Routine Events and Adjustments Oct-2020 for more details.

SECTION 3 - M&V FRAMEWORK AND OPTIONS

3.1 BASIC EQUATIONS OF M&V[10]

Energy, demand, water, greenhouse gas emissions, or other saving in a facility cannot be directly measured, because saving represent the absence of energy/water consumption or demand. Instead, saving are determined by comparing measured energy consumption or demand before and after implementation of an energy saving measure (ESM), 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 shown as mentioned below:

Equation 1:

Saving = (Baseline Period Energy – Reporting Period Energy) +/- Adjustments

A general time series graph representing Energy Consumption (or Demand) during the Baseline Period, the Installation Period, and the Reporting Period is shown below in Figure (4). Adjusted Baseline Energy shown in Figure (4), represents Baseline Period Energy +/- Adjustments (from Equation 1) in the Reporting Period. Adjustments may be both routine and non-routine. The difference between Adjusted Baseline Energy and Reporting Period Energy results in Saving (Avoided Energy Consumption or Demand).

[10] *Source: IPMVP Core Concepts Mar 2022*

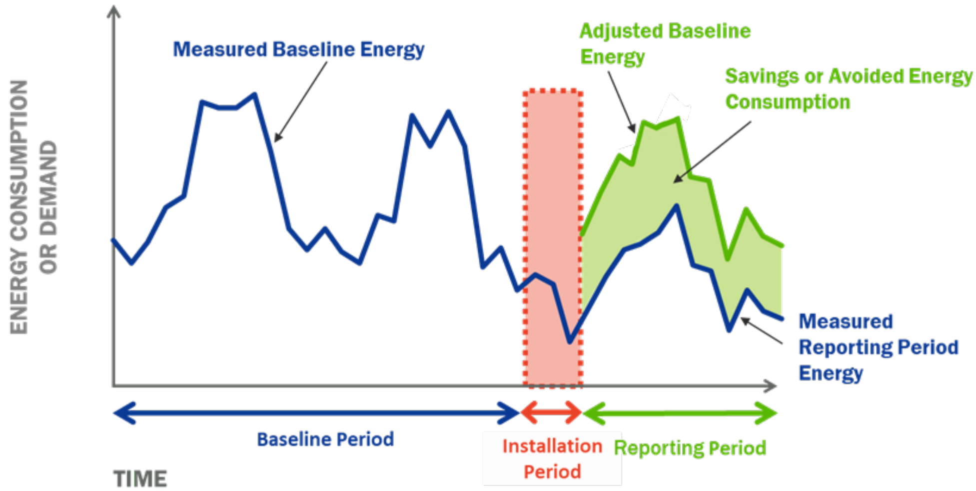


Figure 4 Saving or Avoided Energy Consumption (or Demand)

3.2 The Four Basic Options for Conducting M&V[11]

Saving may be determined for an entire facility or a portion of a facility, depending upon the characteristics of the ESM(s) and the purpose of the reporting.

The measurement boundary is used to isolate the equipment and related energy use which are impacted by the ESM(s) from those unaffected by the ESM(s). All energy used within the boundary must be measured or estimated using meters at the measurement boundary.

The two basic types of measurement boundaries typically used are whole facility and retrofit isolation, as shown below in Figure (5). Note that energy flows from all energy sources impacted crossing the measurement boundary should be measured, and in some cases, such as on-site solar generation, energy may flow in reverse.

[11] Source: IPMVP Core Concepts 2022

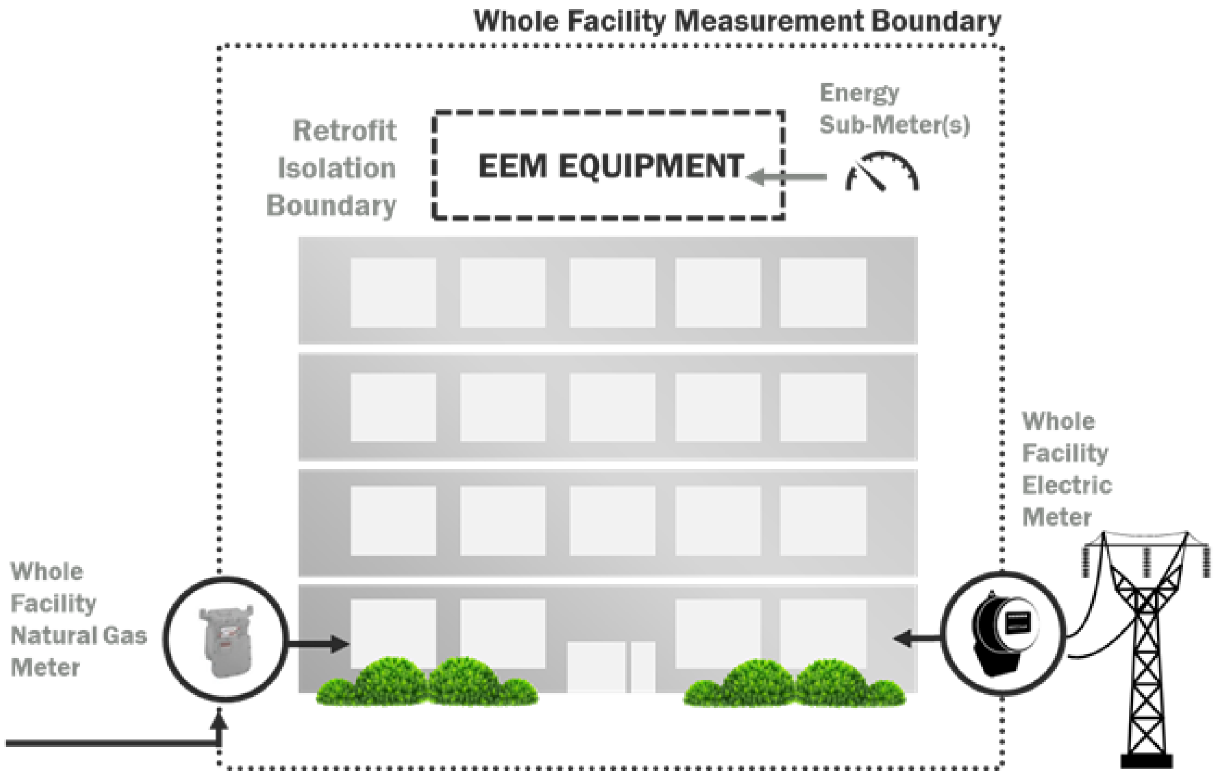


Figure 5 Whole Facility and Retrofit Isolation Measurement Boundaries

The type of measurement boundary selected generally correlates with one or more of the four IPMVP Options and will impact the granularity of the saving reported and measurements required.

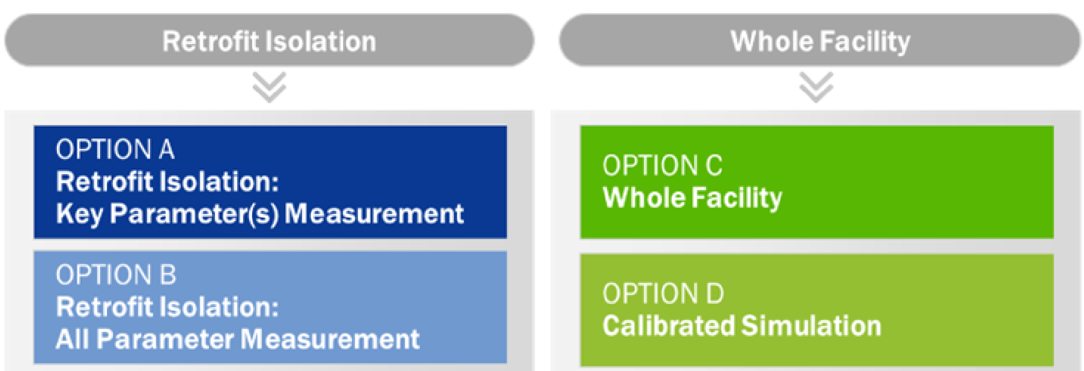


Figure 6 Measurement Boundary

As can be inferred from above Figure (6), the IPMVP options provide the capabilities to measure and verify energy saving in a wide range of retrofit circumstances.

3.3 Selecting An IPMVP Option

Determining the IPMVP Option(s) and measurement boundary that best suits the ESM(s) or overall project requires consideration of the physical properties of how the ESM(s) save energy, the level of saving expected, the need for accuracy and granularity in verified saving reported, and the budget for M&V.

3.3.1 Consider the Measurement Boundary

IPMVP Options (A, B, C, and D) are generally delineated by the measurement boundary used — either a retrofit isolation or a whole facility approach.

Table 3 Consider the Measurement Boundary

IPMVP Options	Type of Measurement Boundary	Measurements Required and Saving Reported
OPTION A: Key Parameter(s) Measurement OPTION B: All Parameter Measurement	RETROFIT ISOLATION	Measures the energy impacts at the equipment or system level
		Saving are determined for each ESM and changes beyond the measurement boundary are estimated or ignored
		Usually requires one or more dedicated meters
OPTION C: Whole Facility OPTION D: Calibrated Simulation	WHOLE FACILITY (or Portion of Facility)	Measures ALL energy effects in a facility or portion of a facility
		Saving include all ESMs and any other changes in energy use
		Often uses the utility meter(s)

Generally, it is not advised to use both retrofit isolation and whole facility M&V Options concurrently since measurement boundaries should not overlap. The requirements for performance verification and reporting may be adjusted during the reporting period, however, and can involve changing to a different IPMVP Option.

Each project's circumstances will largely dictate if a retrofit isolation approach or a whole facility approach should be used.

Retrofit isolation allows the narrowing of the measurement boundary to reduce the effort required to monitor independent variables and static factors when ESMs affect only a portion of the facility. However, boundaries smaller than the total facility usually require additional meters at the measurement boundary and introduce the possibility of significant 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 and unrelated to the ESM will not be reported by retrofit-isolation techniques but will be included in the utility's metered consumption or demand. Otherwise, saving determined through whole facility approaches can be related to utility bills. However, normalized energy saving may difference.

3.3.2 Consider Interactive Effects

Isolated metering is placed at the measurement boundary between equipment that the ESM affects and equipment it does not affect. When drawing a measurement boundary, care should be taken to consider all energy-flows affected by the ESM 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 IPMVP saving equations. Only changes affecting energy systems within the measurement boundary, related static factors, and operating variables must be monitored to prepare the adjustments term(s) of the main IPMVP equation.

3.3.3 Consider Energy Measurements Required

The energy quantities in the IPMVP's saving equations can be measured by one or more of the following techniques.

- Utility or fuel supplier invoices or data directly from the utility meter including any adjustments to the readings that the utility makes.
- Meter data from the utility provider.
- Special meters isolating the energy flow to an ESM or portion of a facility from the rest of the facility. These measurements may be periodic or continuous throughout the baseline and reporting periods and may use temporary or permanent meters.
- Separate measurements of the key parameters used in computing energy consumption and demand.
- Measurements of proxy variables after validating the relationship with energy consumption or demand.
- Building energy simulation that is calibrated to actual energy consumption and demand data for the system or facility being modeled during either the baseline or reporting period.
- If a key parameter needed to estimate saving is already known with adequate accuracy or when it is more costly to measure than justified by the increase in certainty of saving, then direct measurement of energy may not be necessary or appropriate. In these cases, estimates may be made of some of the ESM's key parameters, but others must be measured (Option A).

3.3.4 Consider Stability of Operations

Past or future changes in energy use patterns within the measurement boundary due to changes unrelated to the ESMs can influence the Option selected. The need for non-routine adjustments can sometimes be avoided by using a smaller measurement boundary, reducing the number of static factors which may impact the performance of the ESM.

3.3.5 Consider M&V Costs and Uncertainty in Saving[12]

The cost of the M&V effort must be aligned with the value of the project and the expected saving. M&V costs should be appropriate for the level of expected saving, the uncertainty in the reported saving, the impact on ESM payback period, the stakeholders' interests in the accuracy, frequency, and duration of the reporting process. It is difficult to generalize about costs for the different IPMVP Options since each project will have its own budget. However, M&V should incur no more cost than needed to provide adequate certainty and verifiability in the reported saving, consistent with the overall budget for the ESMs.

Option A methods usually have lower cost and higher uncertainty than Option B methods. Since new measurement equipment is often involved in Options A or B, the cost of installing and maintaining this equipment may make Option C less costly for longer reporting periods, but this must be compared to the costs for tracking static factors and making non-routine adjustments. Cost planning for Options A and B should consider all elements: analysis, meter installation, meter calibration, the ongoing cost to read and record data, and perform verification activities.

The acceptable level of uncertainty in a saving report is related to the cost of decreasing uncertainty to an appropriate level for the expected amount of saving. Typically, average annual M&V costs should be less than 10% of the average annual saving being assessed. The quantity of saving at stake, therefore, places a limit on the M&V budget, which in turn may determine how much uncertainty is achievable.

[12] Source: IPMVP Core Concepts 2022

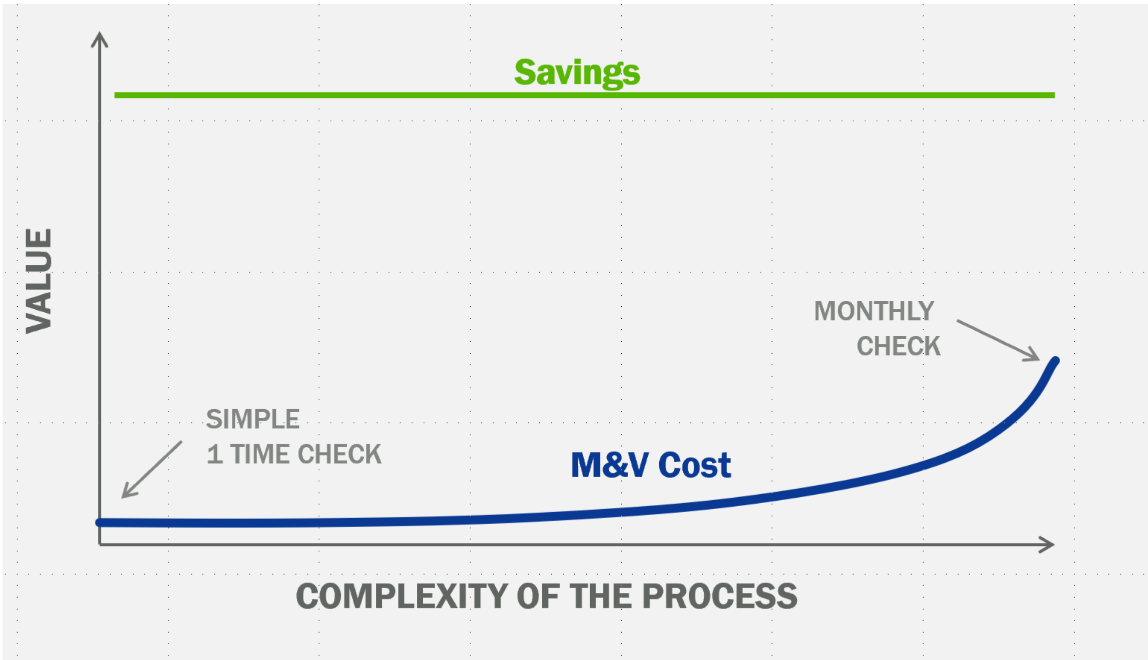


Figure 7 M&V Costs and Uncertainty in Saving

The acceptable level of uncertainty in a saving-reporting process is often a matter for project stakeholders, which depends on their desire for rigor. However, reducing uncertainty requires more or better operational data, which has additional benefits. Enhanced operational data enables fine tuning of ESMs to increase saving and can enhance the use of other operational variables for as performance indicators.

The Uncertainty Assessment for IPMVP EVO 10100–1:2018 presents methods of quantifying uncertainty and present methods of combining several components of uncertainty and setting uncertainty criteria or objectives.

Not all ESMs should expect to achieve the same level of M&V uncertainty since uncertainty is proportional to the complexity of the ESM and the variations in operations during both the baseline period and reporting period. Increasing measurements generally reduces the uncertainty in saving. For example, scheduled indoor lighting loads may use electricity consistently all year, making it relatively easy to determine saving, while heating and cooling loads change seasonally making saving identification more difficult.

3.3.6 Best Applications

It is impossible to generalize on the best IPMVP Option for any type of situation. However, some key project characteristics can be helpful indicators of the best approach.

Retrofit-Isolation Options A and B are best applied when:

- **The physical properties of the ESM allow the impacted energy flows to be separately measured.**
- **Any interactive effects of the ESM on the energy consumption and demand of other facility equipment can be reasonably estimated or assumed to be insignificant.**
- **Only the performance of the systems affected by the ESM is of concern, or saving from each ESM need to be reported.**
- **Expected saving from the ESM(s) are too small to be detected using Option C or to justify the expense of using Option D.**
- **Sub-meters already exist to isolate energy consumption and demand of affected systems, or adding sub-meters would be feasible.**
- **The energy influencing factors (i.e., independent variables and static factors) which affect energy consumption and demand are not excessively difficult or expensive to monitor.**
- **There is no need to directly reconcile saving reports with changes and payments to energy suppliers.**

Whole Facility Options C and D are best applied when:

- **There is a high level of interactive effects from the ESM or energy** interactions between ESMs.

- The energy flows impacted by the ESM(s) cannot be separately measured.
- The level of saving expected is high enough to use Option C and reporting a facility's overall performance, rather than ESM performance, is preferred.
- There are many unique ESMs whose energy flows would be difficult to measure individually.
- Baseline period energy data are not available (Option D).

Some project characteristics and commonly favored Options are shown in **Table (8)**.

Table 4 ESM PROJECT CHARACTERISTIC

ESM PROJECT CHARACTERISTIC	Favored Options			
	A	B	C	D
NEED TO ASSESS ESMS INDIVIDUALLY	✓	✓		✓
NEED TO ASSESS ONLY TOTAL FACILITY PERFORMANCE			✓	✓
EXPECTED SAVING ARE LESS THAN 10% (MONTHLY ENERGY USE DATA) OR 5% (DAILY OR HOURLY ENERGY USE DATA) OF WHOLE FACILITY BASELINE ENERGY CONSUMPTION	✓	✓		✓
THE ENERGY INFLUENCING FACTORS FOR THE ESMS ARE NOT WELL KNOWN		✓	✓	✓
LONG TERM PERFORMANCE ASSESSMENT NEEDED	✓	✓	✓	
INTERACTIVE EFFECTS OF ESM ARE SIGNIFICANT OR UNMEASURABLE			✓	✓
RECENT OR FUTURE CHANGES ARE EXPECTED TO IMPACT ENERGY USE WITHIN THE MEASUREMENT BOUNDARY	✓			✓
BASELINE PERIOD ENERGY DATA ARE NOT AVAILABLE				✓

3.4 KEY ELEMENTS OF THE BASIC M&V FRAMEWORK

3.4.1 Operational Verification

Operational verification consists of a set of activities that help to ensure that the ESM is installed, commissioned, and performing its intended function. Confirmation that Energy Saving Measures are installed and operating as per the design intent and have the potential to perform and generate saving is required. This may involve inspections, functional performance testing, and/or data trending with analysis.

Operational verification serves as a low-cost initial step for assessing saving potential 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.

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

A range of operational verification methods are outlined below. Selection of the best approach to operational verification depends on the ESM's characteristics, the level of saving uncertainty involved, and the magnitude of the saving at risk compared to the cost of verification. Data collected during the operational verification may be used for M&V.

Table 5 Operational Verification

Operational Verification Approach	Typical ESM Application	Activities
Visual Inspection	ESM will perform as anticipated when properly installed. Direct measurement of ESM performance is not possible.	View and verify the physical installation of the ESM. (e.g., windows, insulation, passive devices)
Sample Spot Measurements	Achieved ESM 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 ESM installations. (e.g., fixture power, motor replacement serving constant load)

Operational Verification Approach	Typical ESM Application	Activities
Short-Term Performance Testing	ESM performance may vary depending on actual load, controls or interoperability of components.	Tests for functionality and proper control. Measure key parameters. May involve conducting functional tests designed to capture the component or system operating over its full range or performance data collection over sufficient period of time to characterize the full range of operations. (E.g., Demand Control Ventilation, VFD on Fan or Pump)
Data Trending and Control-Logic Review	ESM performance may vary depending on actual load and controls. Component or system is being monitored and controlled through a Building Automation System (BAS) or can be monitored through independent meters.	Set up trends and review data or control logic. The measurement period may last for a few days to a few weeks, depending on the period needed to capture the full range of performance. (E.g., chiller, boiler, economizer, controls)

3.4.2 Measurement Periods

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 span a full operating cycle from maximum energy consumption and demand to minimum.
- Include only time periods for which factors that impact energy use are known about the facility.

→ Note: The extension of baseline periods backwards in time to include multiple cycles of operation requires equal knowledge of factors that impact energy use throughout the longer baseline period, to properly derive routine and non-routine adjustments after ESM installation.

- Coincide with the period immediately before implementing the energy Saving measures.

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

- Support ESM planning.

→ ESM 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 operating cycle length.

Installation Period

The length of the installation period depends upon the project and ESMs. Measurements and site-inspections during this period may be used to monitor for changes in static factors which could impact saving from the ESMs.

Depending on the M&V Option(s) and measurement boundary selected, reporting period measurements on individual ESMs completed may begin after operational verification is complete. Specific contractual provisions may be needed, however, to accommodate staggered completion of ESMs. In these instances, the reporting period for a project will typically begin when installation of all measures has been verified.

Reporting Period

The developer of the M&V Plan and saving reports should determine the length of the reporting period, which will subsequently be compared to the baseline period energy to develop verified saving. The reporting period should encompass at least one normal operating cycle of the equipment or facility, to fully characterize the saving effectiveness in normal operating modes.

The length of any reporting period should be determined with due consideration of the life of the ESM, the likelihood of degradation of originally achieved saving over time, and the purposes of ongoing saving reporting. The frequency and level of detail reported may change over time.

Energy saving can only be reported for reporting periods that use IPMVP-adherent procedures. If measurements or verified saving from a past reporting period are used as a basis for assuming future saving, future saving reports do not adhere to the IPMVP and are not verified saving.

3.4.3 Methods of Adjustments

The adjustment terms in the IPMVP saving equations should be computed from identifiable physical facts about the characteristics that impact equipment energy use within the measurement boundary. Two types of adjustments are possible: Routine Adjustments and Non-Routine Adjustments.

Routine Adjustments

For any energy influencing 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 parameter equations which correlate 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.

When a change to one or more static factors which significantly impacts energy use in the measurement boundary is identified this becomes a potential non-routine event. When analysis of the non-routine event indicates sufficient impact to the magnitude of energy saving this then warrants making a non-routine adjustment. Sometimes, an adjustment is required to account for baseline equipment problems that must be addressed prior to ESM implementation. In these cases, the baseline energy requires an adjustment so that it reflects operational conditions not actually encountered in situ during the baseline period. This may be required for the baseline energy to reflect intended operations after needed repairs or deficiencies present in the baseline equipment or to meet code requirements. If the baseline energy requires such adjustments, it becomes the 'hypothetical baseline energy', and reporting should include a description of the exact adjustments to the algorithms, variables or terms used to adjust the measured baseline energy. Note that baseline data consist of real facts about energy and independent variables as they existed during the baseline period.

The mechanism of the adjustments made in calculating saving depends upon whether saving are to be reported on the basis of the conditions of the reporting period, reported on the basis of the conditions of the baseline period, or normalized to some other fixed set of conditions.

3.4.4 Basis for Adjustment

The operating conditions that affect energy consumption often differ between the baseline and reporting periods. It is important that reliable adjustments are made to account for these changes in operating conditions. The basis of adjustment specifies the operating conditions under which saving will be evaluated using routine and non-routine adjustments and is defined in the M&V plan.

The basis of adjustment selected determines how the measured energy consumption and demand will be adjusted. Depending on the basis for adjustment used, energy saving are categorized as either Avoided Energy Use or Normalized Energy Saving, as shown in below Figure (8).

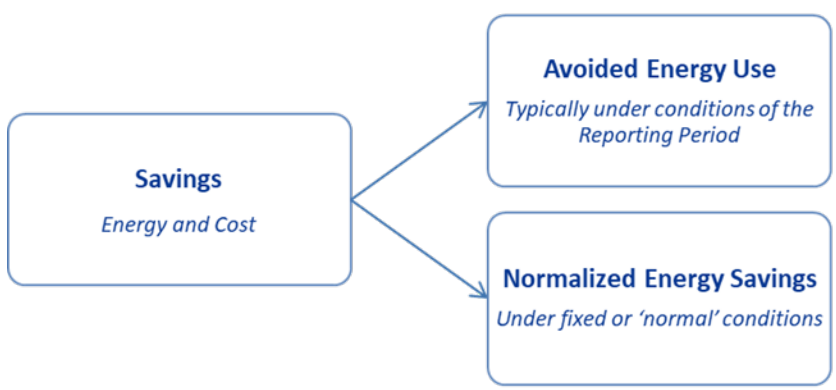


Figure 8 Basis for Adjustment

Avoided Energy Use

Saving stated as avoided energy consumption or demand quantifies reductions

relative to what measured energy or demand would have been without the ESM, most commonly under reporting period conditions.

Avoided Energy Consumption = (Baseline Period Energy Consumption ± Routine Adjustments to Reporting Period Conditions ± Non-Routine Adjustments to Reporting Period Conditions) - Reporting Period Energy Consumption

Normalized Energy Saving

Normalized energy saving use conditions other than those of the reporting or baseline periods as the basis for adjustment. The conditions may be those of an agreed-upon representative period or a typical, average, or normal set of conditions as the basis of adjustment. Adjustments to a fixed set of conditions such as typical meteorological year (TMY) weather data provide a type of saving called normalized energy saving. In this method, the reporting period energy and the baseline period energy are adjusted from their actual conditions to the common fixed conditions.

Normalized Energy Saving = (Baseline Period Energy ± Routine Adjustments to Fixed Conditions ± Non-Routine Adjustments to Fixed Conditions) – (Reporting Period Energy ± Routine Adjustments to Fixed Conditions ± Non-Routine Adjustments to Fixed Conditions)

3.4.5 Statistics for M&V

Statistics are used when summarizing, analyzing, interpreting data, and when evaluating results. They are therefore often required in M&V, including when evaluating measured data, validating any mathematical models developed to routinely adjust energy consumption, when using measurements from a sample of equipment, and when considering uncertainty in saving.

Role of Uncertainty

The measurement of any physical quantity includes errors because no measurement instrument is 100% accurate. The determination of saving is uncertain because saving represents the absence of energy use and cannot be measured, only estimated. Errors are the differences between observed and true energy consumption and demand. In an M&V process, errors prevent the exact determination of saving.

Saving usually involve at least two such measurement errors (baseline period energy and reporting period energy), and whatever error exists in the computed adjustments. To ensure that the resulting uncertainty in the saving estimate is acceptable to the project stakeholders, the errors inherent in measurement and analysis must be managed and assessed when developing and implementing the M&V Plan.

Characteristics of a saving determination process which should be carefully evaluated to manage uncertainty in reported saving are:

- → Instrumentation error – measurement equipment errors are due to calibration, accuracy of instrument, inexact measurement, and improper meter selection or operation. Quantifying modeling error based on accuracy of calibrated instrument is typical.
- → Modeling error – mathematical forms from regression analysis or other techniques do not fully account for all variations in energy consumption or demand. Limited modeling error (uncertainty due to scattering in the data beyond what is characterized by appropriate independent variables) is expected and allowable within appropriate bounds. High levels of modeling error can be due to unusual variations in data, inappropriate functional form, the inclusion of irrelevant variables, or the exclusion of relevant variables. Quantifying modeling error using statistical parameters to calculate uncertainty in saving is typical.
- → Sampling error – use of a sample of the full population of items or events to represent the entire population introduces error as a result of the variation in values within the population, or from biased sampling. Sampling may be performed in either a physical sense (i.e., only x number of the lighting fixtures are measured) or a temporal sense (instantaneous measurement only once per hour). Quantifying sampling error from statistical sampling strategies is typical.
- → Estimated values - error introduced from using any non-measured parameters in saving computation method. Quantifying uncertainty in

saving from estimated values using the range of the expected values is typical.

→ Interactive effects - energy impacts beyond the measurement boundary of the ESMs that are not fully included in the saving computation methodology. Any estimated interactive effects should be small compared to overall saving and conservatively estimated to limit impacts on reported saving.

Using Confidence Levels and Confidence Intervals

Statistical results are based on underlying assumptions along with specified analysis criteria. Where estimated values are based on mathematical Analysis, a confidence level is specified, and the resulting measurement uncertainty is reported – together they express the accuracy of a result. These values are often specified as (confidence level required)/(uncertainty or half confidence interval desired), such as 95/10 or 80/15. Increased levels of rigor are indicated by higher levels of confidence with lower uncertainty (e.g., a result at 95/10 is more accurate than 80/15).

- Confidence level (or level of confidence) refers to the probability that the quoted range contains the true value.
- Confidence Interval (or precision) is the range within which the true value is expected to occur at a specified confidence level (equivalent to twice the saving uncertainty).

Evaluating Results

Different levels of uncertainty may be acceptable. However, the accuracy of any specific model used should be agreed upon by stakeholders, including the mathematical models often used in Options B and C, and the simulation models used in Option D. To this end, specific threshold metrics may be used to assure reasonably accurate models. The level of confidence to be used in Analysis is specified, and the resulting metrics which describe the goodness of fit of a model compared to actual data are reported (e.g., net mean bias error – NMBE, coefficient of variation of root mean squared error – CV(RMSE), and Fractional Saving Uncertainty – FSU). Similarly, it is important to verify the significance of all independent variables included in a model using statistical metrics (e.g., t-statistic >2).

Statistical regression models may be required to meet certain minimum criteria to ensure the validity of reported saving results. Such assessments are necessary to 1) validate the significance of independent variables, 2) ensure a model is of sufficient accuracy to determine saving, and 3) to validate the assumptions of regressions[13]. The independent variables used in models to determine saving may be confirmed using a statistical metric (e.g., p-value, t-statistic) based on the specified confidence level and the quantity of data observed.

For a model to be considered valid, its accuracy must be considered relative to the level of saving expected. Specifically, the standard error of the estimate must be less than 50% of the expected saving at a specified confidence level, typically no lower than 68%, although these are modest thresholds. Lower levels of error at confidence levels of 80% to 90% are often preferred in M&V Analysis, and these levels should be included in the M&V plan.

These are minimum threshold values required to ensure the expected level of saving can be determined using a given model. If this threshold is not met, reported saving may not be valid. Similarly, saving may not be fully evident (e.g., "lost in the noise") when uncertainty levels are too high.

Since energy saving are typically summed over time, the error in each value included must be considered. The total uncertainty, however, may not be a simple sum of errors but is usually less (according to probability theory, the sum of independent errors may be simplified to the square root of the sum of the individual error components squared). Additional rules apply, but total uncertainty decreases somewhat over time as the total number of data points increases. Note that special considerations are needed to determine uncertainty when using frequent time-series energy data (e.g., hourly) affected by autocorrelation in the data, as the

[13] Source: IPMVP Core Concepts 2022

simplification in the combination of uncertainty components is no longer applicable. Details and related examples are available in IPMVP Application Guide on Uncertainty Assessment.

3.5 Option A – Retrofit Isolation: Key Parameter(s) Measurement

3.5.1 Overview

Under Option A, Retrofit-Isolation: Key Parameter(s) Measurement, energy quantities are derived from a computation using a combination of measurements of some key 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 saving.

Decide which parameters to measure and which to estimate by considering each parameter's contribution to the overall uncertainty in the reported saving. The estimated values and analysis of their significance should be included in the M&V Plan.

When estimating non-key parameters, a range of plausible values should be determined, and a value selected which results in a conservative saving estimate. The significance of these estimated non-key parameters to the total estimated saving should be determined. Engineering calculations or mathematical modeling should be used to assess the significance of the errors in estimating any parameter in the reported saving. The combined effect of estimations should be assessed before determining whether sufficient measurement is in place.

The selection of which factor(s) (i.e., key parameters and any required performance indicators) to measure may also be considered relative to the objectives of the project or the duties of a contractor undertaking some ESM performance risk. Where a factor is significant to assessing performance of the ESM, it should be measured while other factors can be estimated.

3.5.2 Baseline Definition

Estimates may be based on historical data such as data recorded during an energy audit, operating hours from whole building energy data, equipment manufacturer published ratings, laboratory tests, or typical weather data.

If a parameter, such as hours of use is shown to be constant and not expected to be impacted, the reporting period determination of a parameter can be assumed to be equal to the baseline value or vice versa, but the values would be considered estimates. Wherever a parameter is not measured in the facility during both the baseline period and reporting period, the parameter should be treated as an estimated value.

3.5.3 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 cases where the hours of use are unchanged by the ESM, the general equation may simplify to:

Option A Saving = Estimated Baseline Period Hours of Use x (Baseline Period Measured Rate of Energy Use – Reporting Period Measured Rate of Energy Use)

Saving Uncertainty

The saving uncertainty is the combined uncertainties in the adjusted baseline energy and the adjusted reporting period energy. Sources of saving uncertainty for Option A can result from sampling error where measurements are made on statistical samples, and error based on measurement instrumentation used.

The largest source of uncertainty in saving reported using Option A, however, is typically from estimated values. The plausible range of values for any estimated values should be evaluated, and the resulting range of saving reported. Where statistical sampling is used for measurements, the statically results of the sampling and their impact on verified saving should also be determined.

3.5.4 Best Applications

Option A is best applied where:

- **The level of saving is low and cannot justify the cost of measurements needed for Option B or simulation for Option D.**
- **Estimation of non-key parameters may avoid possibly difficult non-routine adjustments when future changes are likely to happen that affect energy use within the measurement boundary.**
- **Uncertainty created by estimations is acceptable.**
- **Interactive effects are limited or easily estimated.**
- **Continued effectiveness of the ESM can be assessed by simple routine re-testing or re-inspection of key parameters.**
- **Key parameter(s) used to judge a project's or contractor's performance in computing saving can be readily identified.**

3.6 OPTION B - RETROFIT ISOLATION: ALL PARAMETER MEASUREMENT

3.6.1 Overview

Option B, Retrofit-Isolation: All Parameter Measurement, requires measurement of energy and demand quantities to compute energy saving. The saving created by most types of ESMs 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 saving patterns are variable.

3.6.2 Calculations

When energy consumption or demand within the measurement boundary varies based on independent variables routine adjustments may be required. However, in some cases under Option B, there may be no need for adjustments, routine or non-routine, depending upon the location of the measurement boundary, the variability of the measured energy consumption and demand, the length of the baseline period measurements and reporting period measurements, and the amount of time between baseline and reporting period measurements. In such cases, Option B saving equation simplifies to below Equation.

Option B Saving = Baseline Period Energy - Reporting Period Energy

Saving Uncertainty

The saving uncertainty is the combined uncertainties in the adjusted baseline energy and the adjusted reporting period energy. Sources of saving uncertainty for Option B result from error based on measurement instrumentation used and sampling error where statistical samples are measured. These errors should be quantified and included in the verified saving reported.

3.6.3 Best Applications

Option B is best applied where:

- Energy consumption or operations within the measurement boundary are variable and interactive effects are limited.
- The ESM will affect more than one key parameter.
- The ESM's outcome will benefit from monitoring.
- Meters for isolation purposes exist or will be used for other purposes such as operational feedback or tenant billing.
- Measurement of the key parameters is less costly than simulation in Option D.

3.7 OPTION C – WHOLE FACILITY

3.7.1 Overview

Option C involves use of utility meters, whole facility meters, or sub-meters and independent variables to assess the energy performance of a total facility or a portion of a facility. The measurement boundary can encompass either the whole facility or a major section. This option determines the collective saving of ESMs applied within the measurement boundary and as such saving reported under Option C include the positive or negative effects of any non-ESM changes made in the facility.

Option C is intended for projects where expected saving are large relative to the random or unexplained energy variations which occur at the whole facility level. Baseline models are developed to forecast energy consumption and calculate saving, however these models (which are often based on regression analysis) do not account for all variations between the independent variables and the actual energy consumption or demand data. Statistical results of models describe how well the variations in energy consumption are explained. If saving are large compared to the unexplained variations in the baseline period energy data, then identifying saving will be easier. Care should be taken to ensure the baseline period energy represents normal operations and does not include non-routine periods. Also, the longer the reporting period the more data are available, and the less significant is the impact of short-term unexplained variations.

Generally, expected saving needs to be large compared to the error in the baseline model (e.g., greater than twice the standard error in the model). As a general rule, if only monthly utility billing data are available, saving typically should consistently exceed 10% of the baseline period energy to confidently discriminate the saving from the unexplained variations in either the baseline or reporting period data.

When short-time interval energy consumption data (e.g., hourly) 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 can often verify, with confidence expected saving that are lower than 10% of annual energy consumption. In either case, an assessment of baseline model accuracy compared with expected saving is required.

Identifying facility changes that will require non-routine adjustments represents a fundamental component of the Option C approach, particularly for long reporting periods. Therefore, periodic inspections of all equipment and operations in the facility should be performed 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.

3.7.2 Independent Variables

Common independent variables include weather, production volume and occupancy. Weather has many dimensions, but for whole facility analysis, weather data are often limited to 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 saving. This translates to below Equations for Avoided Energy Use and Normalized Energy Saving.

Avoided Energy Consumption = Adjusted Baseline Energy - Reporting Period Energy

+/- Non-Routine Adjustments to Reporting Period Conditions

Normalized Energy Saving = (Baseline Period Energy +/- Routine Adjustments to Fixed Conditions +/- Non-Routine Adjustments to Fixed Conditions) –

(Reporting Period Energy +/- Routine Adjustments to Fixed Conditions +/- Non-Routine Adjustments to Fixed Conditions)

Independent variables should be measured and recorded during the same period as the energy data.

3.7.3 Calculations & Mathematical Models[14]

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

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 usually uses 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 ensure 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

[14] Source: NSW M&V Process Guide

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 saving. When verifying demand saving using models built from short interval data, it may be preferable to use only previous days of similar weather conditions, since those days are most likely to be representative of times when high demand occurs.

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.

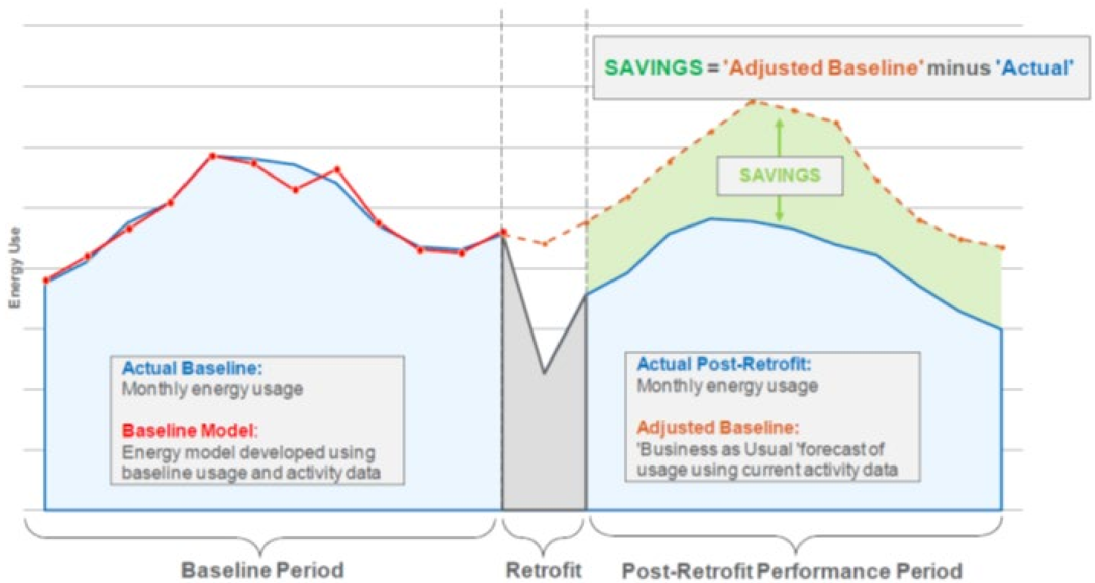


Figure 9 Option C Saving Calculations

Saving Uncertainty

The saving uncertainty is the combined uncertainties in the adjusted baseline energy and the adjusted reporting period energy. Sources of saving uncertainty for Option C include statistical error in mathematical models used and any error based on measurement instrumentation used. These errors should be quantified and included in the verified saving reported.

Quantifying saving uncertainty for Option C can be complex and depends how "wellbehaved" a building is and the resultant scatter in the data and similarly in the reporting period model, if used, the resulting uncertainty in saving can be calculated using statistical parameters from the models, the number of points included, and the length of the reporting period. See the IPMVP Application Guide on Uncertainty for suitable methods.

3.7.4 Best Applications

Option C is best applied where:

- An assessment of the energy performance of the whole facility is of interest, rather than the individual ESMs.
- There are many types of ESMs in one facility.
- ESMs involve activities whose individual energy consumption and demand is difficult to separately measure.
- Saving are large compared to the variance in the baseline and reporting period energy 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 or demand and independent variables.
- Utility data or sub-metered energy data is available in frequent intervals.

3.8 Option D – Calibrated Simulation

3.8.1 Overview

Option D: Calibrated Simulation involves the use of building energy simulation software to predict facility energy use, typically when a baseline does not exist. Saving determined with Option D are based on computer simulation models of physical systems which are used to predict facility or process energy consumption and demand. These types of models are based on engineering equations that capture the physics and details of the systems included in the measurement boundary. The accuracy of the saving depends on user proficiency, model robustness and the level of calibration achieved.

Option D may be used to assess the performance of ESMs for the whole building, akin to Option C. However, the whole building simulation model can also be used to provide an estimate of the saving attributable to each ESM within a multiple ESM 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.

3.8.2 Types of Simulation Programs

Energy 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 where simulations are used for buildings, although compliance may be difficult to verify. 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 ESMs. 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.

For industrial applications there is not a single standard for simulation software. Industry or process specific. Special-purpose software programs may be used to simulate energy use associated with the operation of devices or industrial processes. Proprietary simulation software may also be used if algorithms, calculations, and statistical treatments are transparent and well documented. System-level simulation models may be used if they meet the above criteria and account for ESM interactions.

When metered data for the baseline or existing conditions are available, the simulation model is calibrated so that it predicts the energy and load shapes approximately match the actual metered data. Otherwise, the model should be calibrated to reporting period conditions. The requirements for model calibration should be included in the M&V Plan.

When calibrated, the simulation model should reasonably predict the load shapes and energy use of the facility or system. This is determined by comparing model results to measured energy consumption and demand data, independent variables and static factors and iteratively altering the model until predicted energy consumption and demand as well as key parameters agree with measured data within acceptable limits. The changes made to the model's input parameters to calibrate the model should be documented.

Nominally, calibration of many whole building simulations is performed with twelve consecutive months of utility billing data over a range of weather conditions and a stable operating period. Using shorter time-interval energy data, however, to determine load profiles is common in the calibration process. In a new building, model calibration may not occur until several months after completion when occupancy and operations stabilize. For industrial processes or other facility subsystems, process data should be collected for a sufficient time period to capture a full range of operating conditions including all significant process cycles and variations. Ensure data are of sufficient granularity and frequency to capture variations. The calibration time period and the data to be utilized should be documented in the M&V Plan. Collect and record any data that will be used if evaluating normalized energy saving (e.g., average production rates, weather condition for a standard-year).

Calibration data might include operating characteristics, schedules, occupancy, weather, process or other loads and equipment efficiencies. 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. The level of calibration should be established in the M&V Plan and reflect the level of effort and accuracy justified for the project.

After collecting the calibration data, perform the Calibration Steps as follows:

Table 6 Types of Simulation Programs

Step	Description
1	DEVELOP NECESSARY INPUT PARAMETERS AND MODEL ASSUMPTIONS, AND DOCUMENT THEIR VALUES AND SOURCES.
2	GATHER DATA FROM THE CALIBRATION PERIOD AND DOCUMENT THEIR VALUES AND SOURCES. DATA NEEDED INCLUDES ENERGY CONSUMPTION AND DEMAND DATA AS WELL AS DETAILS ON OTHER ENERGY INFLUENCING FACTORS E.G., MEASURED SYSTEM PRESSURES, TEMPERATURE SET POINTS, MATERIAL FLOWS, OPERATING HOURS, OCCUPANCY LEVELS, ETC. WHERE ESTIMATES ARE USED, DOCUMENT THE RANGE OF LIKELY VALUES.
3	RUN THE SIMULATION MODEL AND VERIFY THAT SYSTEMS MEET PERFORMANCE REQUIREMENTS, E.G. LOADS FOR EACH END-USE, ZONE SET POINTS (TEMPERATURE AND HUMIDITY) FOR BUILDINGS; PRODUCTION RATES AND PRODUCT QUALITY PARAMETERS FOR INDUSTRIAL APPLICATIONS.
4	COMPARE THE SIMULATED ENERGY RESULTS WITH THE METERED ENERGY DATA FROM THE CALIBRATION – ON AN HOURLY, DAILY OR MONTHLY BASIS.
5	COMPARE RESULTS TO DETAILED OPERATING AND MEASURED PERFORMANCE DATA TO ENSURE THEY REPRESENT ACTUAL FACILITY AND SYSTEM OPERATION.
6	EVALUATE CONSISTENCY IN LOAD SHAPES AND OTHER END USE PATTERNS AND CALIBRATION DATA. E.G. BAR CHARTS, MONTHLY PERCENT DIFFERENCE TIME SERIES GRAPHS, AND MONTHLY XY SCATTER PLOTS HELP TO IDENTIFY DISCREPANCIES.
7	AS NEEDED, REVISE INPUT DATA VALUES ESTABLISHED IN STEP ONE. REPEAT STEPS 3 – 5 TO BRING PREDICTED RESULTS WITHIN THE PROJECT CALIBRATION REQUIREMENTS WHICH WERE SPECIFIED IN THE M&V PLAN. COLLECT MORE OPERATING DATA FROM THE FACILITY IF NECESSARY.
8	SIMULATION MODEL CREATION AND CALIBRATION IS AN ITERATIVE PROCESS THAT CAN BE TIME CONSUMING. USING MONTHLY OR DAILY RATHER THAN HOURLY ENERGY DATA HELPS TO LIMIT THE EFFORT NEEDED FOR CALIBRATION AND COST OF PERFORMING MODEL CALIBRATION. HOWEVER, IF THE SIMULATION WILL BE USED TO DETERMINE DEMAND SAVING OR SAVING AT THE ESM LEVEL, CALIBRATION USING HOURLY OR DAILY DATA (OR IN SOME CASES SHORTER TIME INTERVAL DATA) IS REQUIRED FOR THE IMPACTED SYSTEMS AND/OR EQUIPMENT.

3.8.3 Calculations

Avoided energy consumption can be determined using the measured reporting period energy and demand along with the calibrated simulation results from models representing the baseline period and the reporting period.

Existing Building

For existing buildings, an energy model representing existing building conditions is developed to predict the impact of the ESMs. After ESMs are installed, the reporting period energy consumption and demand is used to calibrate the reporting period model with the installed ESMs. Once calibrated, the ESMs are removed from the model to create the baseline model. This model represents the existing building performance under the reporting period conditions.

Normalized energy saving can also be determined. If it is desired to report saving under normal conditions, the reporting period calibrated model would be modified to represent normal conditions (e.g., normal weather conditions or normal variables) then the ESMs would be removed to develop the baseline model.

New Construction

If the baseline period does not exist (e.g., new construction or repurposing of a building), the reporting period calibrated model can be used 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 ESMs removed, as described above.

Since the model is only calibrated to one period, the calibration error is assumed to equally affect the baseline period and reporting period models. In this scenario, the calibration error is the actual reporting period energy minus the energy predicted by the calibrated model for the reporting period, and the adjusted baseline period energy is the baseline period energy predicted by the model under reporting period conditions plus the calibration error, which can be either positive or negative.

Avoided Energy Consumption =	Baseline Period Energy from the Calibrated Model updated to Baseline Conditions - Reporting Period Energy from the Calibrated Model

Ongoing Saving

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 ESMs are installed. In later years, Option C may be applied with the baseline period based on the metered data from the reporting period's first year of steady operation. In this case, Option C is used in subsequent years to track saving persistence.

3.8.4 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, or**
  - **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 ESM installation.**
- **There are too many ESMs to assess using Options A or B.**
- **Performance of each ESM will be estimated individually within a multiple ESM project, but the costs of Options A or B are excessive.**
- **Interactions between ESMs are complex and significant, making the isolation techniques of Options A and B impractical.**

SECTION 4 – M&V PLAN CONTENTS

A key requirement in ESPC projects is development and implementation of a clear and transparent project-specific M&V Plan that describes all the 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 saving can be verified with adequate certainty. For performance contracting projects where the M&V Plan defines how saving will be verified to ensure the contractual saving 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 ESMs.

An adherent M&V Plan is one that meets all the criteria presented below in items 1 through 15. It is required that each of these points be addressed in the site-specific M&V Plan. An adherence criteria checklist is attached as a separate Annex.

4.1 FACILITY AND PROJECT OVERVIEW

An 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 relevant energy audit / DFS reports or other analysis that was used to develop the project.

4.2 INTENT OF ENERGY SAVING MEASURE

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 detailed description of the measure,

→ How the measure saves energy, demand, or other resources (e.g., improves efficiency, reduces operating hours, etc.),

- → The measure's effect on operational factors such as temperature setpoints, hours of operation, etc. and if the measure will correct any operational deficiencies,
- → An inventory of impacted equipment, and
- → Expected saving estimated in energy units, and the source of estimate.

4.3 Selected IPMVP Option and Measurement Boundary

Specify the IPMVP option that will be used to evaluate saving. Clearly 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 saving. Quantified interactive effects should also be included in this section with appropriate justification.

4.4 Baseline: Period, Energy Use 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 saving determination.

Baseline documentation should include the following information:

Identification of the Baseline Period

Identify the specific time period over which the operation and conditions of the facility or system are assessed and documented prior to the implementation of

ESMs. This baseline period is often a year but can be any period depending on the specific M&V needs.

Baseline Energy Consumption and Demand Data

The baseline energy consumption and demand data may include utility billing data and/or meter interval data if Options C or D are used, or meter interval data, spot measurements, or short-term measurement data if Options A or B are used. This includes the energy data collected over the baseline period. These data are normally considered to be dependent variables.

Data Representing Energy Influencing Factors

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 independent variables.

Baseline Operating Conditions

Define the prevailing operating conditions corresponding to the dependent and independent variables (e.g., Baseline Energy Consumption and Demand Data, Independent Variable(s) 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.

4.5 Operational Verification Requirements

Specify the operational verification activities that are required after ESM installation to confirm the installation is complete, meets specifications, and has the potential to save energy as expected. This section should include:

- What data will be collected to confirm the ESM is properly installed and meets the ESM's Intent.
- Who is responsible for conducting these verification activities.
- If these activities are to be repeated during the reporting period, when and by whom.
- What will be reported regarding the verification activities conducted.

4.6 Reporting Period

Specify the operational verification activities that are required after ESM installation to confirm the installation is complete, meets specifications, and has the potential to save energy as expected.

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 ESCO is required to report on the performance of the project and the ESMs on a regular basis for the entire duration of the performance period.

4.7 BASIS FOR ADJUSTMENTS

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 saving are reported as avoided energy or as normalized saving.

There may be a requirement to account for baseline equipment problems or code compliance issues that must be addressed prior to ESM 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.

The M&V Plan should provide a description of the criteria and methods for making relevant non-routine adjustments to account for unexpected changes in the reporting period. Non-routine adjustments may require revising the model and recalculating the adjusted baseline period energy and the adjusted reporting period energy use to properly determine saving.

Describe methods that will be used in making any non-routine adjustments and criteria for when these adjustments will be required in order to properly calculate saving. Refer to specific procedures from IPMVP's Application Guide on Non-Routine Events and Adjustments.

4.8 CALCULATION METHODOLOGY AND ANALYSIS PROCEDURE

The M&V Plan needs to specify data analysis procedures, model descriptions, and assumptions that are used to calculate saving for each of the reporting periods. The IPMVP saving equation(s) used should be included.

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, R2, t-statistic, etc.) or other model elements or terms. Report the range of independent variables over which the models are valid.

4.9 ENERGY PRICES

The M&V Plan should also specify the utility prices, or tariffs that will be used to calculate the cost saving associated with the measure or project, and how the monetary value of saving 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.

4.10 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 specifications including - type, make, model, as well as the range, resolution, accuracy, and precision of readings,**

- **Data to be collected, formats, and related responsibilities**
- **Meter reading and witnessing protocol, if required**
- **The installation procedures for new or temporary meters,**
- **Calibration requirements and procedures**
- **Details for data collection and transfer**

4.11 MONITORING AND REPORTING RESPONSIBILITIES

The plan should state responsibilities for collecting, analyzing, archiving, and reporting the data. Management of M&V data should be assigned to the party that is qualified to manage access and provide data sets efficiently and effectively. Responsibilities should include as a minimum:

- **Acquisition of Energy and Independent Variable data**
- **Management of measurement equipment and systems**
- **Monitoring of Static factors impacting energy use within the measurement boundary**
- **Operational verification and periodic inspections**

4.12 EXPECTED ACCURACY

The M&V Plan should include the expected accuracy of the reported energy saving. Describe sources of uncertainty in the saving such as measurement, data capture, sampling, modeling, and data analysis, and describe uncertainty assessment to be used in the planned saving report.

This assessment should include qualitative and any feasible quantitative measures related to assessing the level of uncertainty in the saving. Report all uncertainty factors, either qualitatively or quantitatively.

Please refer to Uncertainty Application Guide for IPMVP as necessary.

4.13 M&V BUDGET

The M&V Plan should include the budget and the resources required for M&V activities including saving determination, costs for both the initial setup and ongoing tasks for evaluating, documenting the baseline period conditions and for

reporting the estimated saving and other performance metrics required for each of the Reporting periods.

4.14 M&V Saving Report Format

The plan should detail the agreed format and content for reporting the M&V results during the reporting period, including the frequency of reporting. The distribution of the report/s and any requirements for formal review and issuance should be stated. Refer to **Section (5)** – M&V Saving Report for further details.

4.15 Quality Assurance

The M&V Plan should include quality-assurance procedures and processes that will be used in baseline and post-retrofit data collection, calculations, saving reports, and any interim steps in preparing reports.

Quality assurance procedures should include:

- Inspections at regular frequencies to ensure that the measure and equipment continue to be operated as intended.
- Methods of dealing with lost or missing data

Other activities may include:

- Requirements for third-party oversight or review
- Peer review of saving calculations
- Assessing the accuracy of measurement methods
- Calculating uncertainty in saving
- Methods of dealing with lost or missing data

4.16 Additional M&V Plan Requirements

<u>For Option A</u>

Justification of Estimates

The M&V Plan should clearly identify the variables to be estimated as part of the saving calculation and their impact on the uncertainty in saving. This must include the actual values used and the source of the estimated values. Show the overall significance of these estimates to the total expected saving by reporting the range of possible saving associated with the range of plausible values of the estimated parameters.

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. This can include checking any estimated values to ensure that they are still valid.

<u>For Option C</u>

Meters Included

All fuels used within the measurement boundary should be included in Analysis. Justification for excluding any fuels should be provided.

Software Identification

The M&V Plan should include the name and the version number of any software or data analysis package that is used to calculate saving.

Energy and Independent Variable Data

The M&V Plan should describe the source of all energy and independent variable data and the processes used to obtain and manage the data. The data used should be reported, and raw data should be archived and made available as needed. This may include interval data, utility invoices, weather data, and data on other independent variables.

The M&V Plan and Report should provide copies of the energy, weather, and other data used in the Analysis, including any input and output files and/or reports. Details on any data post-processing used, including analysis methods, tools, and calculations should be provided.

Model Fit Metrics

The M&V Plan should include the goodness of fit statistics from the selected model (e.g., confidence level, Standard Error, CV(RMSE), R^2, Net Mean Bias Error, t-statistic for independent variables), and the goodness of fit criteria required for the baseline energy model to be acceptable given the level of saving expected. Include the range of the independent variables covered by the model and the range for which it will be considered valid in the reporting period.

The M&V Reports should similarly detail the goodness of fit metrics for reporting period models. Although not required, it is best practice to calculate uncertainty in saving and to report the range of possible saving values.

For Option D

Software Identification

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

Input/Output Data

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

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.

Model Calibration

The plan should report the energy and operating data that will be used for calibration, including the calibration requirements (e.g., CV{RMSE}, MBE, etc.) and the accuracy with which the simulation results must match the calibration energy data and actual facility conditions. Supporting data should be provided at a minimum of one-month (i.e., billing period) intervals, but more resolution is preferred, and include a description of the steps taken to calibrate the simulation model. M&V Reports should also include model calibration results, as specified in Section (3.8).

Justification of Estimates

The M&V Plan should clearly identify the variables estimated as part of the saving calculation and their impact on the uncertainty in saving. This must include the actual values used and the source of estimated values. Although not required, it is best practice to show the overall significance of these estimates to the total expected saving by reporting the range of possible saving associated with the range of plausible values of the estimated parameters.

SECTION 5 – M&V SAVING REPORT

Periodic M&V reports are prepared to document and communicate the findings of the measurement and verification project using procedures outlined in the M&V Plan. The frequency and the format for these M&V reports must be defined in the M&V Plan. Verification of saving can be performed by an independent party, or by the project developer as long as quality assurance oversight is performed by an appropriately qualified person.

The report should include, as a minimum, the following information:

Overview of M&V Report

- Date of M&V Report.
- Author and Reviewer of the M&V Report.
- Reference to the relevant M&V Plan.
- Key parties included in the distribution of the published report.
- Entities/individuals involved in the reporting period activities.
- Quality assurance procedures and actions taken.

Project Background

- M&V Option chosen for the ESM or project as part of the M&V Plan.
- Description of ESM(s).
- Reporting period start and end dates and frequency of M&V Reports.

M&V Data Collection Activities Conducted During Current Reporting Period

- Start and end time for the measurement period.
- Energy and key parameter data collected.
- Data for independent variables and static factors.
- Description of and findings from inspection activities conducted.
- Installation period activities including details related to operational verification activities conducted, if not yet reported.

Saving Calculations and Methodology

- Provide a detailed description of data analysis and methodology.
- Provide an updated list of assumptions and sources of data used in the

calculations.

- **Provide details of any baseline or saving adjustments, including routine and non-routine adjustments to account for changes. Previous non-routine adjustments should be included if they impact reported saving.**

Verified Saving

- **Include a clear presentation of all energy and demand saving, cost saving, and a comparison of the expected saving.**
- **Discuss sources of uncertainty. If required, provide estimated uncertainty in reported saving.**
- **Provide details of values used to calculate the value of reported saving, if required, and the source of the values (e.g., utility rate or contract details).**

Additional Information Required

All additional items required for the M&V Plan for a specific Option should also be included in the M&V Reports, including those specified above as 'Additional Requirements' for Options A, C, and D.

SECTION 6 – M&V FOR RENEWABLES

Renewable energy (RE) technologies utilize highly diverse resources and conversion technologies. Nevertheless, the technologies share several commonalities distinguishing them from energy efficiency projects. Foremost among these, all renewable energy technologies supply energy rather than reduce energy consumed.

Measuring the amount of energy actually supplied can, in some cases, serve as a simplified approach to measuring system performance in contrast to measurement and verification (M&V) for efficiency measures, which must quantify the amount of energy not used. If the energy supplied depends on a variable renewable energy source, system performance should consider the resource conditions during the monitoring and verification period to differentiate the effect of the underlying resource from the RE system performance. Measurement of actual system delivery is often evaluated by comparing it to a model that predicts what the output should have been under measured conditions.

Renewable energy projects may require a longer investment term or performance contract period than energy-efficiency projects. For example, Power Purchase

Agreement (PPA) periods typically exceed ten years. Therefore, an M&V program for renewable energy may need to verify sustained benefits over longer time periods. This situation favors M&V approaches, initially costing more but returning benefits over a longer time period. An M&V plan based on periodically, and remotely, analyzing data from an onsite Data Acquisition System (DAS) is one example.

For typical project-based M&V Plans that focus on the measurement of the RE system delivery, as the key performance metric, a corresponding measurement of the baseline system performance is not required or applicable since the output measurement defines the performance of the system. Though, there may not be an M&V defined baseline, there are still baseline activities and analysis which must be undertaken during project development for overall RE system M&V and project application and design.

Depending on the project, the M&V activities could involve the detailed review and analysis of the existing facility energy use profiles (electric interval data; hourly load data (electric and/or thermal)). in addition, to the review and analysis of the utility purchasing rate structures, and detailed review and analysis of the local weather conditions related to the RE system performance.

The contract structure shall govern the RE projects' M&V activities, including the baseline analysis, measurements post-installation, and monitoring all static factors and the independent variables.

For an ESCO in a guaranteed performance contract, where RE delivery is the measured performance, the results of the baseline analysis would be used to define the contractual utility rates and to calculate the financial value of the saving. The ambient environmental conditions would also be monitored to determine any unusual weather conditions (different than the historical data used in the baseline project development activities) that could impact the delivered performance of the

RE system. The project specific M&V plan shall illustrate the methodology of measuring these conditions and how to adjust the performance output.

Renewable energy technologies generally rely on variable resources, such as sunlight or wind, to generate useful energy. Consequently, M&V activities must account for these resources' variability, particularly when evaluating predicted or modeled performance, which relies on TMY (typical meteorological year) or similar data.

For example, if using Option B to measure a wind energy system's output over a 12-month reporting period, it is important to understand whether the 12-month monitoring period corresponds to a high, low, or average wind year. Extrapolating long-term saving using data from an atypical weather year could lead to significant calculation errors. Thus, monitoring RE system performance shall include underlying resource of the RE systems in addition to the system output.

If a direct, linear relationship exists between weather measurements and energy generation, a simple ratio of long-term and monitoring period weather values can be used to modify the renewable energy system's monitored performance. The exact method of applying this modified resource varies by technology. For some applications, a linear adjustment is sufficient. Other technologies, such as wind turbines, require more sophisticated statistical treatment. Often, computer models for system design and performance prediction are used to generate and estimate energy yield of the system considering the measured weather data during the reporting period.

Option A, generally is the simplest and least expensive of the IPMVP options, though it provides a less accurate measure of actual system performance. Under Option A, the evaluator, developer, or ESCO uses short-term measurements and observations to determine the operating characteristics of the system and applies the results to project long-term data and to calculate energy saving.

While Option A may require some measurement of system generation (key parameter), it is typically done over a short period of time for purposes of correlating with other variables. Option A can often be exercised using data gathered during a commissioning or start up process. However, the key parameter measurement should be re-measured periodically during the reporting period.

Using Option B, the supplier takes responsibility for metered energy delivery. The renewable resource available is taken into account when establishing whether the system is meeting performance expectations or not.

For example, typically in a performance contract, the ESCO would use an Option B approach utilizing the resource data to adjust, as appropriate, to the verified saving per the methodology defined in the M&V Plan.

Option C analyzes the available information through utility bills or whole-facility metering to determine energy saving or production. After renewable energy system installation, the utility bill (which substitute the measurement) or utility meter reading is subtracted from a baseline, with adjustments for changes in facility's operations to determine energy saving.

The accuracy of option C can be limited by numerous variables affecting building energy use. These limitations make Option C unsuitable for evaluating the performance of systems with small energy outputs, compared to a building's overall electrical load.

Option D relies on comprehensive whole-building or systems models to determine performance and estimate project saving. This option is commonly used in new construction projects with extensive efficiency and/or renewable energy components, where difficulty occurs in isolated metering and baseline characterizations. Though isolated component metering may be conducted to support simulation calibration as part of Option D, this does not constitute the focus of M&V activities.

REFERENCES

IPMVP Core Concepts (EVO 10000 – 1:2016) October 2016

IPMVP Core Concepts (EVO 10000-1:2022) – March 2022

NSW M&V Operational Guide

IPMVP M&V – Issues & Examples February 2019 (EVO 10300 – 1:2019)

Uncertainty Assessment for IPMVP July 2019 (EVO 10100 – 1:2019)

IPMVP Renewables Application Guide March 2017 (EVO 10200 – 1:2017)

IPMVP Application Guide on Non-routine Events and Adjustments October 2020 (EVO 10400 – 1:2020)

EVO PMVA Training Presentation Deck

BPA M&V Guides 2012

ASHRAE Guideline 14-2014

ANNEXES

ANNEX A

M&V Plan Template

Project Overview:

Table 7 Project Overview

Project name	
Project Number	
Entity Name	
Entity Address	
Acronym	
ESCO Name	
Report number	
Date of Report	
M&V Option	
Number of Buildings in the project	
Number of SEC Meters	
SEC Account number/s	
Entity Annual Baseline Consumption (kWh)	
Annual Energy Saving (kWh)	
Percentage of saving %	
Total built up Area (sqm)	

Consumption	Annual Consumption Before	Annual Consumption After	Energy saving in kWh	Energy cost saving in SAR	% Annual Energy Saving	M&V Option
Electricity	XXXX kWh	XXXX kWh	XXXX kWh	XXX SAR	xx%	C

Latitude, Longitude	

Table 8 Saving Summary

Facility Description:

A complete written summary about the facility which includes the energy consumption systems that being considered for this project. Facility coordinates and a picture of the facility from google earth should be added. Any other related details to description facility should be mentioned as well.

Saving Summary:

The above table will summarize the overall saving expected from this project as estimated by the ESCO.

ESM Saving Proposed:

The following table summarizes the Energy Saving Measures for this project:

Table 9 ESM Saving

S/N	Energy Saving Measures	Saving	Cost Saving
		kWh/year	SAR/year
1	Lighting	xxxx	xxxx
2	HVAC Replacement	xxxx	xxxx

...	......	xxxx	xxxx
Total		xxxx	xxxx

<u>Energy Rates:</u>

Saudi Electric Company (SEC) charges a flat rate of 0.32 SAR/kWh. In this proposal, all energy consumption and saving will be associated with a cost based on the 0.32 SAR/kWh flat rate. This rate will be constant for the entire project period.

<u>Baseline Period, Energy, and Static Factors:</u>

<u>Baseline Period</u>

The baseline period according to the meters starts on mm/dd/yyyy, and ends on mm/dd/yyyy, corresponding to a one-year period. The table below summarizes the project's building, feeders, and total annual electricity consumption.

Table 10 Meter Details

Location (Served Area)	All Buildings	
Account no		
Meter no		

<u>Baseline energy consumption</u>

The baseline consumption according to the meters is xxxxxxxx kWh. The monthly consumption is as shown in the below table:

Table 11 Baseline Energy Consumption

From	To	Number of Days	CDD	kWh
mm/dd/yyyy	mm/dd/yyyy	xx	xx	xxxx
mm/dd/yyyy	mm/dd/yyyy	xx	xx	xxxx
Total				xxxx

*CDD Source.

Baseline Static Factors

Static factors include equipment and operating characteristics that are recorded as part of the Detailed Feasibility Study (DFS). There is no change anticipated in the M&V plan for these factors. However, if a change occurs in the data and parameters, the baseline must be adjusted (permanently or temporarily). The list below identifies potential static factors could be used for projects

Table 12 Static Factor

Static factors	No's/capacity/percentage/Values
Building or area utilization	xx
Building occupancy rate	xx
Building floor area	xx
Number and capacity of heating, ventilation, and air conditioning systems (HVAC)	xx
Building standards and legislation governing ambient conditions	xx
Building utilization schedule	xx
Hours of operation of HVAC systems	xx
Lighting hours of operations	xx
Outdoor air supply rate	xx
Temperature setpoints	xx
Hot and chilled water temperature	xx

Because no change was observed in the static factors prior to or during the baseline period, it is not possible to generalize the change in energy consumption that might result from future changes to these values.

<u>M&V Approach:</u>

<u>Measurement Option and Boundary</u>

For this project, Option C was selected as the preferred approach. Electricity will be measured at the SEC electric meter, making the boundary the entire building.

The Option C approach taken will be consistent with guidance outlined in the International Performance Measurement & Verification Protocol Core Concepts (IPMVP, 2022) and the Energy Saving Measurement and Verification User Guide for the Kingdom of Saudi Arabia version 2.

Justification:

Option C was selected as the preferred approach for the following reasons:

- Multiple ESMs interact and saving isolation using Options A/B is complex. Option C will capture the interactions and report the aggregate saving.
- Saving are large (> 10%) relative to the baseline and can be readily determined from utility bill evaluation.
- Baseline electricity consumption is strongly correlated to weather (CDD) such that it is possible to account for changes to weather conditions.
- Monthly meter data is readily available from SEC.
- The facility has a history of consistent occupancy and schedule which is expected to continue for the foreseeable future. This reduces or eliminates the need for multiple baseline adjustments due to changes in static factors.
- The cost of evaluating one (or two, or three) utility meters is low relative to the value of the reported saving.

Estimated Saving:

The following ESMs are proposed for this facility. Estimated saving are based on spot and trend measurements, estimated operating parameters, engineering calculations, and/or hourly building simulation models. Interactions between ESMs have been included in the total saving.

Table 13 ESM Details

ESM name or number	Technology Category	Proposed M&V option (IPMVP A, B, C or D)	Measured variables (Baseline)	Assumed variables (Baseline)	Estimated Saving, (kWh/year)
ESM 1	Lighting	C	Power, kW	Hours	
ESM 2	HVAC		Load, tons Power, kW	CDD (TMY)	
...	Controls		Power, kW	Hours	
....					
Total					

Monthly Saving:

The following is the monthly saving table for each Energy Saving Measures for this project:

Table 14 Monthly Saving Breakdown

ESM	Annual Saving (kWh)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ESM1													
ESM2													
ESM3													
ESM4													
ESM5													
Total	0	0	0	0	0	0	0	0	0	0	0	0	0

Baseline Development:

Independent variables

Independent variables include factors that can affect the facility's energy consumption or demand and that will be systematically included to determine the periodic adjustment of the baseline during the reporting period. For electricity consumption, the most relevant independent variable is the cooling degree-days (CDD), as shown in table below. Cooling degree-days are calculated on a reference of 18.5°C, but the balance point temperature may be adjusted to improve the correlation.

The primary drive of energy use at this facility is weather. The following table lists the monthly energy consumption along with the cooling degree-days corresponding to the billing period. Weather data was obtained from…

Table 15 Independent Variables

From	To	CDD
mm/dd/yyyy	mm/dd/yyyy	xx
mm/dd/yyyy	mm/dd/yyyy	xx

<u>Description of the Baseline Adjustment Methodology</u>

Please provide the methods for baseline adjustment according to changes in independent variables.

Saving are defined as the avoided energy use, which can be calculated as the adjusted baseline less the current consumption. In this case, the adjusted baseline is calculated from a baseline model that correlates energy use to local weather conditions.

$$\text{Saving} = \left(\text{Consumption}_{\text{Baseline}} - \text{Consumption}_{\text{Reporting Period}}\right) \pm \text{Adjustments}_{\text{Routine}} \pm \text{Adjustments}_{\text{Non-Routine}}$$

In this case, the adjustments are derived from the baseline model as shown in the example below: (Please use actual data)

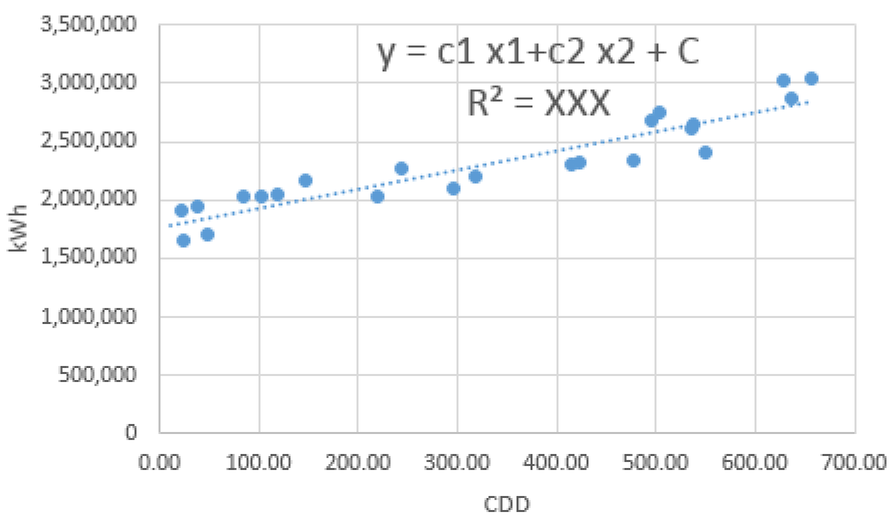


Figure 10 Regression Model

Baseline electricity consumption data are adjusted according to the following equation:

$y = c_1 x_1 + C$

where

y = Adjusted electricity consumption (kWh);

x_1 = Cooling degree-days (°C);

c_1 = Slope (or coefficient of CDD);

C = Baseload consumption (kWh).

The regression analysis is considered satisfactory according to generally accepted standards for this type of analysis. Please provide the statistical indicators for this regression in following table.

Table 16 Statistical Parameters for Regression Model

Multiple Coefficient of Determination	Value	Recommendations
Coefficient of determination (R^2)	xx	> 0.75
Standard Error of the Estimate (month)	xx	
Coefficient of variation of the RMSE CvRMSE = SEE / average(kWh/mo)	xx	< 0.2
t-statistic (for baseline consumption)	xx	ABS(t) > 2
t-statistic (for variable x1)	xx	ABS(t) > 2
t-statistic (for variable x2)	xx	ABS(t) > 2

Non-routine Adjustments (NRAs)

Please provide non-routine Baseline adjustment in case of equipment addition/removal/shutdown or change in operation.

If there are future changes to the defined static factors that require a baseline adjustment, ESCO will propose what the baseline adjustment should be and will implement a mutually agreeable solution.

Expected Accuracy:

The IPMVP defines acceptable accuracy of the reported saving as being twice the standard error of the baseline model. Based on the SE of the baseline regression model and the expected saving, we expect the uncertainty to be xx% of the reported saving.

Please provide if the accuracy on saving has been calculated as per a) Hypothesis: B) Method or C) Results

Table 17 Confidence Interval

Energy	Expected accuracy on guaranteed saving	Confidence interval on Guaranteed saving (Sa)	Confidence Level
Electricity	+/- xx%	xx% <=Sa=> xx%	xx%

<u>Meter Specifications:</u>

For Option C, the IPMVP defines the utility meters as 'perfect' as it forms the basis for all energy costs and cost saving. EES will be installing digital meters to monitor the consumption in real-time, but these meters will only be used for the live monitoring and "fine tuning" of the facility's consumption.

<u>Performance Period Activities</u>

Although the primary measurement & verification will be through utility bill evaluation, ESCO proposes to conduct the following on-site activities on at least an annual basis to verify and maintain performance:

- Conduct annual inspections to verify that all equipment, software, and control sequences are functional, up to date, and operational. Ensure that systems and sequences have not been bypassed or overridden.
- Verify that performance levels (e.g., lighting, temperature, ventilation, etc.) are within acceptable limits.
- Ensure that Entity-provided operations & maintenance activities are being conducted as per manufacturer's and ESCO's recommendations.

- Confirm that no significant changes relating to defined static factors has occurred. If so, document what changes have occurred, when, and propose a non-routine baseline adjustment for review and acceptance.

Reporting period:

The reporting period starts after ESM implementation. The reporting period is indeterminate, and reconciliation will be performed at a minimum of annually for the term of the contract. A one-year reporting period corresponds to a period of 12 consecutive months. The reporting period starts on the date of substantial completion of implemented ESMs

Monitoring Responsibilities

Table: Monitoring Responsibilities – **Energy Data**

Table 18 Responsibilities for collecting Energy Data.

Person in Charge	Data	Frequency
xxxx	xxx	xxx
	xx	

Table: Monitoring Responsibilities – **Independent Variables**

Table 19 Responsibilities for collecting Independent Variables

Person in Charge	Data	Frequency
xxxx	(e.g. Cooling Degree Days – collected from xxx)	xx

	Others xxx	xxx

Table: Monitoring Responsibilities – **Static Factors**

Table 20 Responsibilities for collecting Static Factors.

Person in Charge	Data	Frequency
xx	**(e.g., Changes in occupancy schedules)**	xx
	(e.g., Changes in systems schedules)	
	(e.g. Equipment addition/removal/shutdown in the building)	xx

A) Report Responsibilities

Table 21 Report Responsibilities

Person in Charge	xxx
Frequency	xxxx
Date of Transmission	xxxx

B) Budget

Please provide the budget allotted for metering and sub-metering implementation

Table 22 Metering Budget

Period	Instrumentation	Readings/Analysis/Report
Baseline Period	xxxx	xxx
Reporting Period		xxx

C) Format of M&V Report

M&V reports will be developed annually, presenting the results of the analysis, and descriptions of any adjustments applied to the baseline period. The report format will adhere to the IPMVP Core Concepts-2016, Section 8.0.

At a minimum, the report will include the following sections:

- Project background
- A brief description of the ESMs and the chosen Option
- Reporting period of the report
- A summary with the following:
    - Date/time of any recorded measurements.
    - Data of energy consumption.
    - Data for independent variables and static factors.
    - Detailed description of:
        - any inspection activities.
        - saving calculations and the followed methodology.
        - data analysis and the followed methodology.
        - list of any assumptions.
        - any baseline adjustments.
        - utility costs used in the calculations.
    - Provide a clear presentation of the verified saving, cost saving, and comparison to the guaranteed proposed saving.

Quality Assurance:

The following procedure will be used to ensure the quality of the energy saving calculations and all other related activities in preparing the reports.

- Only professionals with Performance Measurement and Verification Analyst (PMVA), Performance Measurement and Verification Expert (PMVE), Certified Measurement and Verification Professional (CMVP) certification, Professional Engineers (PE), or Certified Energy Manager (CEM) may calculate the saving and adjustments. Moreover, all saving calculations will be based on fundamental engineering principles and performed to the best of the knowledge of the professionals involved. Each calculation will be verified by another person who knows the project and has the required skills.

- All saving calculations will be based on the energy and water data (electricity, etc.) from the copies of the bills from the meters.
- Independent variables: All meteorological data will come from the same source, more specifically, from the weather station located nearest to the project site, at xxx. The Occupancy data will be provided by the Client. The quality / Accuracy of occupancy data will be taken as correct for saving calculations.
- Static factor: Information related to project static factor changes will be sent by the project's internal supervisor (ESCO) to be analyzed by the accredited professional to determine the direct and indirect impacts on projected saving. This professional will then be able to make the necessary adjustments for the reference year to determine the real saving of the measures implemented.

ANNEX B

Regression Based Energy Models

Description:

Regression is a statistical technique that estimates the dependence of a variable of interest (such as energy consumption) on one or more independent variables, such as ambient temperature. It can be used to estimate the effects on the dependent variable of a given independent variable while controlling for the influence of other variables at the same time. It is a powerful and flexible technique that can be used in a variety of ways when measuring and verifying the impact of energy efficiency projects.

In M&V, energy usage is the dependent variable, whether energy usage is measured monthly through bills or measured more frequently through meter monitoring. The regression model attempts to predict the value of the dependent variable based on the values of independent, or explanatory, variables such as weather data.

Dependent Variable – the outcome or predicted variable; for M&V, the dependent variable is typically energy use
Independent Variable – an explanatory variable; a variable whose variation explains variation in the dependent variable; for M&V, weather characteristics are often among the independent variables
Simple Linear Regression – a regression with a single independent variable
Multiple Linear Regression – a regression with two or more independent variables

One of the most common applications of regression in M&V is when the primary source of data is monthly utility consumption. The initial step is to establish the baseline dependence of building usage on weather conditions by creating a model for the baseline period. Then, post-retrofit weather is applied to the baseline model in order to estimate the energy use of the building had the energy efficiency improvements not been made (the counterfactual situation). In M&V, this projection of the baseline energy use as per the conditions of the reporting period is called the adjusted baseline. Finally, the adjusted baseline (predicted counterfactual energy use) is compared to the actual post-retrofit energy use and the difference provides an estimate of energy avoidance saving.

The ideal case for regression is when the measurement period captures the full annual variation in the dependent and independent variables – that is, the full range of operation conditions. If the relationship between the independent and dependent variables is not expected to change over the range of operating conditions, then short-term measurements can be extrapolated to annual energy use, even if the measurement period does not capture the full annual variation. A particular advantage of regression is that it not only facilitates an estimate of energy saving, but it also can provide an estimate of the uncertainty in saving calculations.

Although simple in concept, proper use of regression requires a clear understanding of statistical methods. Regression models require multiple observations on the dependent and independent (explanatory) variables. There are times, however, when data for explanatory variables are not readily available. Explanatory variables that are not included in the regression model often introduce added error. If energy use is not a strong function of the independent variable(s) in the equation, or if there is large variability in energy use ("scatter" in the x-y chart) relative to strength of the predictive relationship, regression analysis generates estimates that have high uncertainty.

<u>Regression Process:</u>

1. Identifying all Independent Variables

To properly identify all independent variables, you should consider the facility and how different factors play into its energy use. Then, you will compile a list of the variables that are likely to have an impact on the energy use of the facility or system being modeled. When variable values are not continuous, the data can be separated into several regression models with categorical variables, rather than including all possible variables within a single model.

Some independent variables commonly used in energy regressions are:

- Ambient dry bulb temperature (actual or averaged over a time-period such as a day)
- Cooling Degree Days
- Plant Output (number of widgets produced in some period)
- Number of Occupants / Room Occupancy

2. Collect Data

Prior to installation of the measure, identify and collect data for a monitoring period that is
representative of the facility, operation, or equipment. This is the baseline period and should be long enough to represent the full range of operating conditions. For example, when using monthly data for a weather-sensitive measure, the baseline period typically includes 12 or 24 months of billing data, or several weeks of meter data. Using a partial year may overemphasize portions of the year and add variability to your model. It is vital that the collected baseline data accurately represent the operation of the system before improvements were made. Anomalies in these data can have a large effect on the determination of saving. Examine data outliers – data points that do not conform to the typical distribution – and seek an explanation for their occurrence. Atypical events that result in outliers include equipment failure, any situations resulting in abnormal closures of the facility, and a malfunctioning of the metering equipment. Truly anomalous data should be removed from the data set, as they do not describe the operations prior to the installation of the measure.

3. Synchronize the Data

To accurately represent each independent variable, the intervals of observation must be consistent across all variables. For example, a regression model using monthly utility bills as the outcome variable requires that all other variables originally collected as hourly, daily, or weekly data be converted into monthly data points. In such a case, it is common practice to average points of daily data over the course of a month, yielding synchronized monthly data. There are problems with this approach because varying data lengths may cause bias in the model.

4. Graph the Data

Create one or more scatter plots to begin to visualize the relationships between the dependent and independent variables. Please note that the independent variable should be on the X axis and the dependent variable on the Y axis.

5. Select and Develop Model

To create a baseline equation, perform a regression analysis on the measured variables. The
analysis is typically called an ordinary least squares regression because the tool generates a model that minimizes the sum of squared deviations between the actual and predicted values.

The equation calculated from the regression analysis represents the baseline relationship between the variables of interest. Frequently, however, more than one independent variable influences the outcome variable. For example, the electricity used by a chiller system might be affected by variations in outside temperature, relative humidity, hours of facility use, and number of occupants. To accurately model cooling energy consumption, we need to include additional independent variables, creating a multiple regression model.

6. Validating Regression Model

Once you have created a baseline model, you can generate the following statistical measures or tests to help validate that your estimated model relationships provide a good description of the data. At a minimum, use the following three measures to determine if your baseline equation is appropriate:

- R^2
- CV(RMSE) Coefficient of Variation of the Root Mean Squared Error
- Mean Bias Error
- t-statistic
- p-value

7. Requirements for Regression

There are four requirements for using regression based on OLS. They are:

- Linearity: There must exist a linear relationship between variables.
- Independence: Two or more regressor variables are independent if their conditional
- probability distributions are unrelated.
- Normality: Residuals should be normally distributed.
- Homoscedasticity: Under assumptions of homoscedasticity, different response variables will have the same variance in their errors, regardless of the values of the predictor variables.

Common Issues with Regression Analysis:

To provide accurate predictions, the sample of data used for a regression model should be
representative of the overall population. For energy M&V, the baseline modeling period should cover most of the full range of operating conditions.

Option C usually uses complete years (e.g., twelve, twenty-four, or thirty-six months) of continuous data during the baseline period and continuous data during the reporting period. For short time interval data, fewer months of data may be used; however, care should be taken to ensure 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.

Another difficulty in using utility bills is that the billing period may be different for different months. You may think that using (heating or cooling) degree-days addresses this issue, because the value of the independent variable would go up as the number of days in a month increases. However, the degree-day observations only affect the slope portion of the equation, yet the intercept of the equation might also be affected. A common way to address this issue of varying days in a month is to standardize data into daily units, such that the independent variable is expressed as degree-days per day, and the dependent variable is expressed as energy-use-per-day.

One other note regarding the common approach to regression employing the ordinary least squares method to determine regression lines: The squaring used to get the mean squared error weights outliers more than methods based on simple differences, assigning relatively greater importance to large errors than to small ones. Therefore, if the data has outliers, they should be understood and removed if not representing operating conditions.

Creating Regression Models:

This section describes the various types of linear regression models that are commonly used for M&V. In certain circumstances, other model functional forms, such as second-order or higher polynomial functions, may be valuable. The M&V practitioner should always graph the data in a scatter chart to verify the type of curve that best fits the data.

1. Mean Model

Mean models uses the mean of the dependent variable as the best predictor for future values and are the simplest models. They are not really regression models but are included here for the sake of completeness. A mean model would describe energy use that is not related to any significant independent variables.

2. Simple Linear Regression

Two parameter (2P) models are the simple linear regression models with which most M&V practitioners are familiar using popular spreadsheet software. They are appropriate for modeling building energy use that varies linearly with a single independent variable, such as ambient temperature. In most commercial buildings, metered whole-building energy use varies linearly with ambient temperature above 65° F due to changes in cooling energy use. Please refer to the case study in the next section for detailed explanation on creating simple linear regression models.

3. Simple Linear Regression with Change Point

Some systems are dependent on a variable, but only above or below a certain value. For example, cooling energy use may be proportional to ambient temperature, yet only above a certain threshold. When ambient temperature decreases to below the threshold, the cooling energy use does not continue to decrease at the same rate.

Similar behavior is often seen in building gas usage because the heating energy is proportional to ambient temperature during the space heating season and the energy associated with hot water use is constant across all seasons. In cases like these, simple regression can be improved by using a change-point linear regression.

Change point models often have a better fit than a simple regression, especially when modeling energy usage for a facility. A better fit means a lower model error and hence reduced uncertainty.

Because of the physical characteristics of buildings, the data points have a natural 2-line angled pattern to them. Sometimes it may be appropriate to use multiple change points. The below table and diagrams from ASHRAE Guideline 14 illustrate the major models used for temperature-dependent loads.

Name	Independent Variables	Form	Examples
No adjustment/ constant model	None	$E = E_b$	Non-weather-sensitive demand.
Day-adjusted model	None	$E = E_b \times \text{day}_b/\text{day}_c$	Non-weather-sensitive use (fuel in summer, electricity in summer).
Two-parameter model	Temperature	$E = C + B_1(T)$	
Three-parameter models	Degree days/ temperature	$E = C + B_1(DD_{BT})$ $E = C + B_1(B_2 - T)^+$ $E = C + B_1(T - B_2)^+$	Seasonal weather-sensitive use (fuel in winter, electricity in summer for cooling); seasonal weather-sensitive demand.
Four-parameter, change-point model	Temperature	$E = C + B_1(B_3 - T)^+ - B_2(T - B_3)^+$ $E = C - B_1(B_3 - T)^+ - B_2(T - B_3)^+$	Seasonal weather-sensitive-use buildings with two cooling or two heating modes (i.e., two weather-sensitive slopes with one change point).
Five-parameter models	Degree days/ temperature	$E = C - B_1(DD_{TH}) + B_2(DD_{TC})$ $E = C + B_1(B_3 - T)^+ + B_2(T - B_4)^+$	Heating and cooling supplied by same meter. Change point $B_3 < B_4$; otherwise use four-parameter model.
Multivariate models	Degree days/ temperature, other independent variables	Combination form $E = c_0 + c_1x_1 + c_2x_2 + ... + c_nx_n$	Energy-use-dependent non-temperature-based variables (occupancy, production, etc.). Linear model form shown.

Figure 11 Type of Regression Models

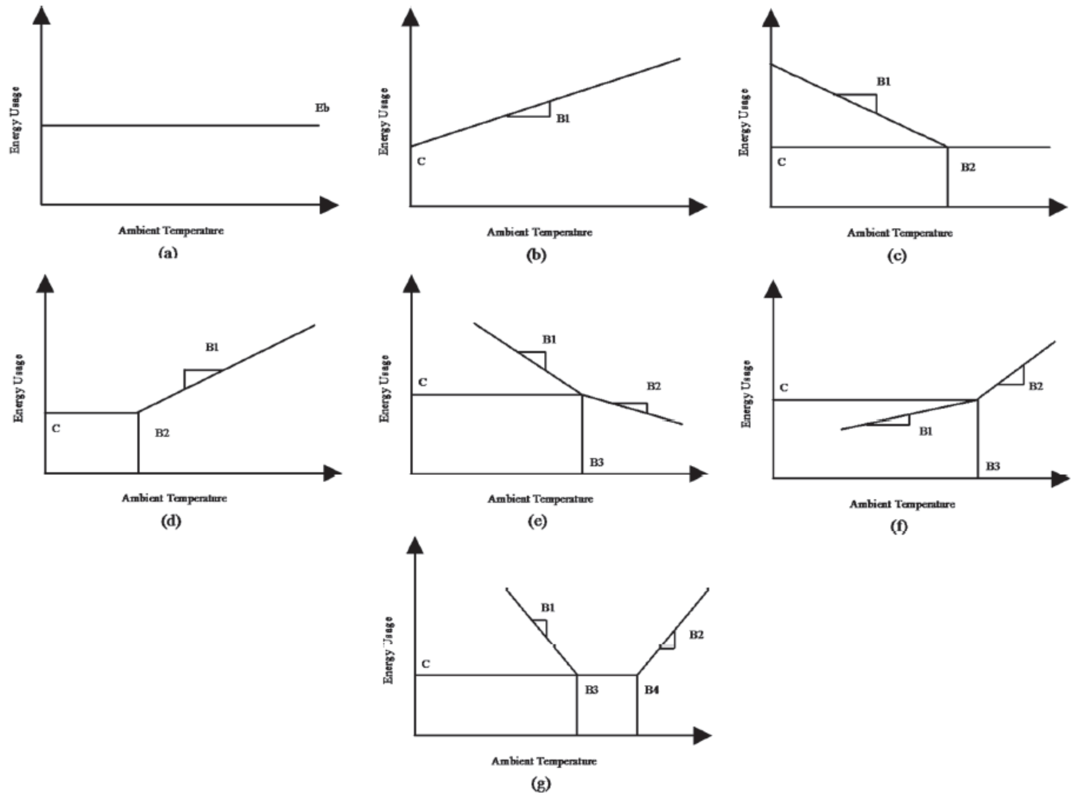


Figure 12 Relation Types of Independent Variables

Sample models for the whole-building approach: (a) mean, or one-parameter model; (b) two-parameter model; (c) three-parameter heating model (d) three-parameter cooling model (e) four-parameter heating model (f) four-parameter cooling model (g) five-parameter model.

4. Multiple Linear Regression

The models discussed thus far have all used a single independent variable. Of course, for many building systems, energy use is dependent on more than one variable. In such cases, single variable models will typically result in low R^2 values.

In such cases, including other variables that are known to influence energy usage will provide a more accurate model. Commonly used variables which can significantly affect energy use include occupancy, humidity, events, etc.

Simple regression can be visualized as fitting a line. Multiple regression models with two independent variables fit a plane, and a three variable model fits a 3-dimensional space.

With multiple regression, additional independent variables will always increase the model's fit. However, this does not necessarily mean that the model is improved, since a model can be overfitting if additional independent variables are not statistically significant, or the additional variables are correlated with other independent variables already included in the model. However, this can be checked if t-stat or P–value in regression output.

<u>Case Study – Simple Linear Regression</u>

In sites where air conditioning and refrigeration is used, energy use can often be modelled against ambient air temperature. Within these systems a constant temperature is desired to maintain a comfortable space, yet the ambient outside temperature fluctuates during a day, and throughout the year. Energy use of the system will usually vary in direct proportion to the differential between the desired internal temperature and the ambient external conditions. This effect applies to comfort heating and cooling systems.

An energy use model can be developed to describe this relationship. This involves:

1. Determining an average temperature
2. Selecting a base temperature, known as a balance point
3. Calculating the difference between the daily average and the balance point to determine the heating or cooling requirement. This figure is known as a 'degree day'.
4. Summing the degree days over the intended period to align with business cycles

The use of degree days is a powerful tool to assist with establishing energy model based on weather correction.

Degree days imply the amount of work that needs to be done to achieve the base conditions given the changing ambient ones. One key advantage of degree days is that, unlike temperatures, the figures can be aggregated into weeks, months and years, which allows comparison with periodic energy use data, or for normalization.

Then cooling degree days (CDDs) for a day is calculated as follows:

$$CDDs = Daily\ average\ temperature - Cooling\ balance\ point$$

- CDDs > 0 when daily average temperature > cooling balance point
- CDDs = 0 when daily average <= cooling balance point

This is due to the inherent nature of the system, where cooling is only required where the external temperature exceeds the target value – otherwise the cooling system will not operate.

Figure below illustrates the weekly energy use of a building vs CDD:

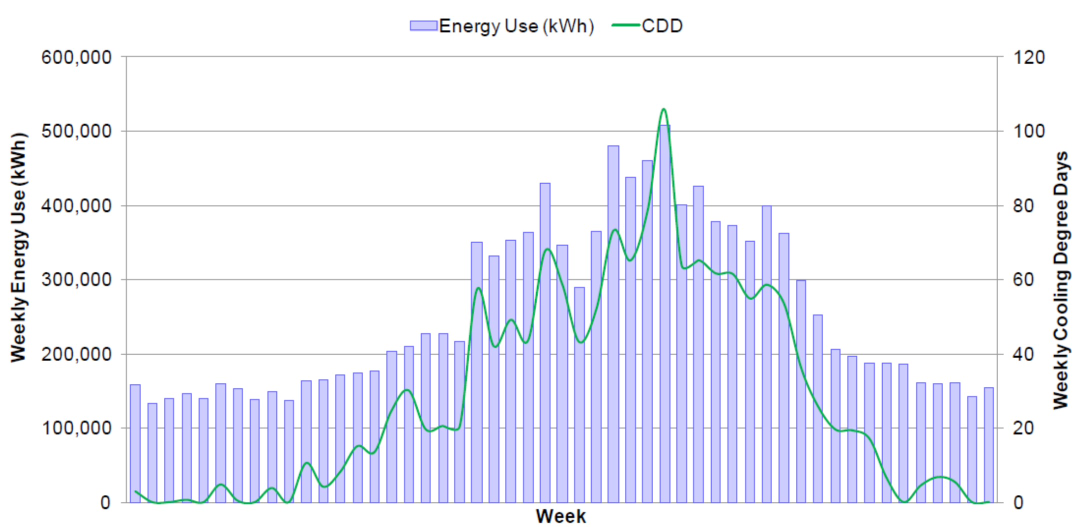


Figure 13 Weekly Energy Use vs CDD

It should be noted that not all usage can be attributed to ambient temperature. For example, a typical air conditioning system may operate year-round to remove heat from people and appliances. More generally, energy usage patterns will be attributed to a combination of static factors and variables.

As a result, the bars in the chart above can be divided into fixed and variable components.

It is the variable part that we wish to understand and evaluate in the context of the independent variables. Finally, we can analyze the relationship using an XY scatter chart from which we can observe the direct relationship between CDDs and energy use. This is illustrated in the chart below:

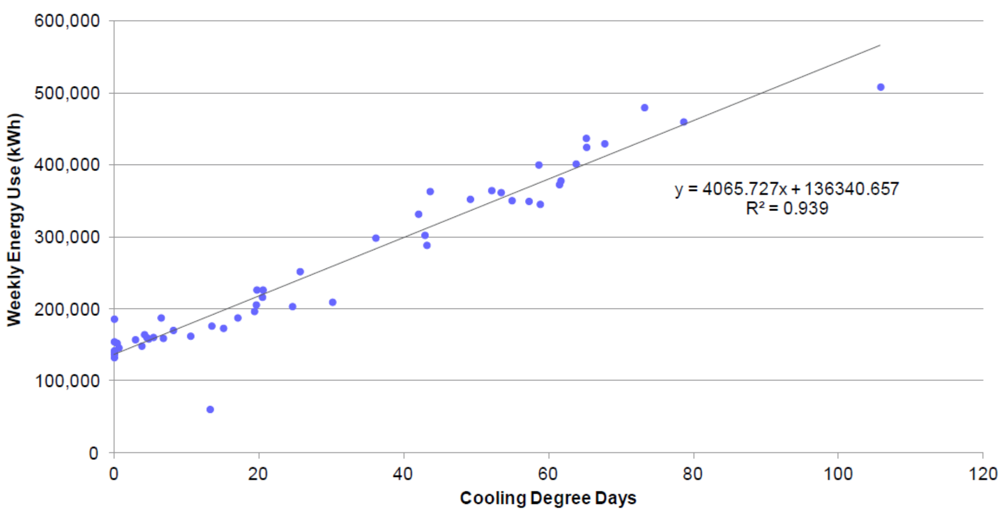


Figure 14 Regression Model

The arrangement of the 'dots' shows a clear trend. A trend line is added to the chart to establish the trend, which is essentially a linear regression. The resulting equation becomes the energy model that describes energy use as a function of CDDs.

The energy model for this building is:

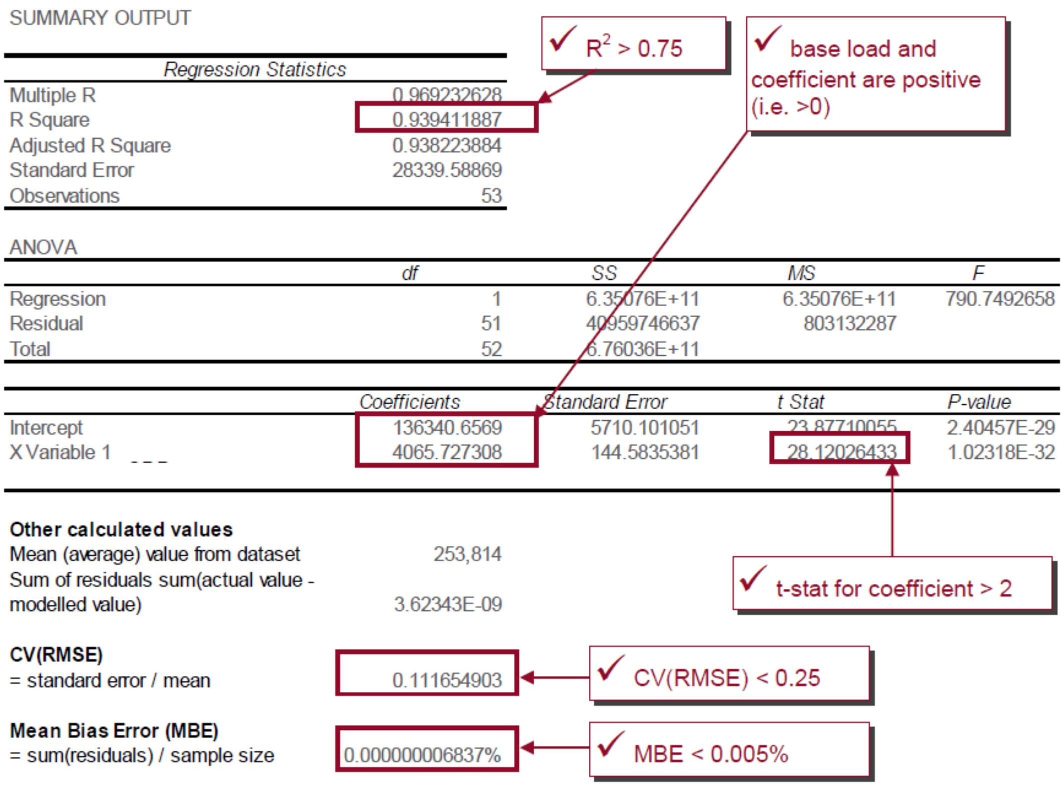
$$Energy\ use\ (kWh) = 136{,}340.657\ kWh + 4{,}065.727 \times (CDDs)$$

As mentioned, the equation reveals that weekly energy usage will be approximately 136,000 kWh when value for CDD is zero. Usage will increase by approximately 4,066 kWh per week for each additional CDD. The energy model can now be applied to estimate energy use across alternate time periods where ambient temperature is gathered CDDs are calculated.

Validating the model

Using the validation tests defined earlier, we can confirm the validity of the model. Following a visual inspection, we can look at the regression analysis output generated by the modelling software (Microsoft Excel in this case).

From the statistical validation tests shown in the Figure below, we can be satisfied that our model is appropriate.



SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.969232628
R Square	0.939411887
Adjusted R Square	0.938223884
Standard Error	28339.58869
Observations	53

ANOVA

	df	SS	MS	F
Regression	1	6.35076E+11	6.35076E+11	790.7492658
Residual	51	40959746637	803132287	
Total	52	6.76036E+11		

	Coefficients	Standard Error	t Stat	P-value
Intercept	136340.6569	5710.101051	23.87710055	2.40457E-29
X Variable 1	4065.727308	144.5835381	28.12026433	1.02318E-32

Other calculated values	
Mean (average) value from dataset	253,814
Sum of residuals sum(actual value - modelled value)	3.62343E-09
CV(RMSE) = standard error / mean	0.111654903
Mean Bias Error (MBE) = sum(residuals) / sample size	0.000000006837%

Figure 15 Statistical Parameters

Evaluating the uncertainty of the regression model:

The uncertainty inherent in the regression model should be determined and evaluated against any internal or external minimum thresholds for precision and confidence level.

Using the regression model standard error (SE) of ± 28,339.59 kWh from the results in Figure above, the absolute precision can be calculated for a range of confidence levels using t statistic values.

Absolute precision (AP) is calculated as: AP = $t \times SE$

Relative precision (RP) is calculated as: RP = AP / $estimate$

where the $estimate$ is the predicted value from the regression model after the independent
variables have been substituted into the regression model.

<u>Adjusting a model for post-retrofit conditions:</u>

After all the effort to that went into developing and tuning the baseline model, adjusting it for post-retrofit conditions is straightforward. We simply need to apply the regression equation and input the desired variables.

The model can be adjusted to meet actual conditions within a desired period in order to determine ‘actual saving’. Alternatively, the model can be adjusted using a ‘standard’ set of conditions in order to determine ‘normalized’ saving.

ANNEX C

Regression Based Energy Models

Table 23 Regression Based Energy Models

#	Criteria	Short Description	Review Checklist
1	Facility and Project Overview	- 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. - Provide references to any energy audit reports or other analysis that was used to scope the project.	- Is the overall project description adequate and clear? - Are project analysis and design documents available?
2	ESM Intent	- Describe the ESM, its intended result and how saving are being realized.	- Is the ESM description clear? - Saving description clear?
3	Selected M&V Option & Measurement Boundary	- Specify the chosen M&V Option - Identify the measurement boundary of the saving determination. - Describe the nature of any interactive effects beyond the measurement boundary together with their possible effects and actions taken if any.	- Is appropriate and correct M&V guideline and option used? - Measurement boundary clearly identified? - Are the interactive effects quantified? - Do M&V activities match declared M&V option?
4	Baseline - Period, Usage & Conditions	- Identification of baseline period - Identify and include baseline energy consumption data - Identify and include operational data coinciding with the energy data - Identify and include static factors that might affect baseline energy data.	- Identification of the baseline period (i.e., start and end dates, etc.) - Identification of current equipment condition - Are required baseline energy consumption included? - Are required independent and operational data included? - Are static factors coinciding with the energy data identified?
5	Operational Verification Requirements	- Specify the operational verification activities that are required after ESM installation to confirm the installation is complete, meets specifications, and has the potential to save energy as expected.	- What data will be collected to confirm the ESM is properly installed and meets the ESM's Intent? - Who is responsible for conducting these verification activities? - If these activities are to be repeated during the reporting period, when and by whom? - What will be reported regarding the verification activities conducted?

#	Criteria	Short Description	Review Checklist
6	Reporting Period	- Identify the reporting period	- Is a specific description of the reporting period included? - If the reporting period is a period of time, are start and end dates clearly identified?
7	Basis for Adjustment	- Declare the set of conditions to which all energy measurements will be adjusted (forecast, backcast, chaining). - Describe what anticipated conditions affect energy use and what data and calculations are required to make baseline adjustments. - Describe possible events - expected or unexpected - not directly related to the ESMs but affecting energy use and how their impact will be determined, and how saving would be adjusted based on them.	- Is the basis for adjustment clearly defined? - Are described routine adjustments clearly identified? - Are non-routine adjustments presented and the required data and methodology clearly described? - Is the data required and methodology for adjusting energy use reasonable?
8	Calculation Methodology/Analysis Procedure	- Specify the exact data analysis procedures, algorithms and assumptions to be used in each saving report. For each mathematical model used, report all of its terms and the range of independent variables over which it is valid. - Description of methodology to calculate baseline period energy use. - Description of how baseline adjustments will be made (routine and non-routine) - Description of how saving will be determined (step- by-step preferred) - Description of error analysis/uncertainty, parametric studies conducted	- Were all analysis procedures clearly and logically described? - Was the methodology for describing baseline adjustments clearly described? - Was the methodology for calculating saving clearly described? - Was the error analysis/uncertainty clearly described? - Are all manipulations of data properly documented and follow general engineering methods?
9	Energy Prices	- Specify the energy prices that will be used to value the saving, and whether and how saving prices will be adjusted if prices energy rates change in future	- Are the energy prices and escalation rates clearly identified for each of the energy units? - Is there a plan described for how to adjust the prices annually?

#	Criteria	Short Description	Review Checklist
10	Meter Specifications	- For non-utility meters, specify: meter characteristics (accuracy, resolution), meter commissioning procedure, routine calibration process, and method of dealing with lost data	- Is meter described including make, model, and general characteristics? - Is meter full scale value, units and % accuracy / resolution included? - Is meter calibrated and commissioned? - Is a plan for mitigation of any lost data in place?
11	Monitoring Responsibilities	- Assign responsibilities for recording and reporting the energy data, independent variables and static factors within the measurement boundary during the reporting period and any witnessing requirements.	- Are responsibilities for each of the static and independent variables clearly defined data parameters identified? - Are witnessing requirements described?
12	Expected Accuracy	- Evaluate the expected accuracy associated with the measurement, data capture, sampling, and data analysis. - This assessment should include qualitative and any feasible quantitative measures of the level of uncertainty in the measurements and adjustments to be used in the planned saving report	- Are the saving uncertainties identified? (sources of error?) - Are the uncertainties properly categorized into sampling, measurement, modeling type? - Is overall uncertainty calculated?
13	Budget	- Define the budget and the resources required for the saving determination, both initial setup costs and ongoing costs throughout the reporting period.	- Are M&V costs including setup costs, costs of gathering data, data analysis costs, report generation costs identified? Are those costs reasonable (~3-20% of saving)?
14	Report Format	- Specify how results will be reported and documented. A sample of each report should be included.	- Are the reporting formats clearly described? - Are sample report formats provided?
15	Quality Assurance	- Specify quality-assurance procedures that will be used for saving reports and any interim steps in preparing the reports.	- Are QA/QC Procedures/steps identified? - Are reporting, documentation and QA procedures in place?

ANNEX D

Sampling for M&V

Description:

Proper measurement and verification (M&V) requires actual measurements of the affected
systems. Except in rare instances, it is not cost-effective to measure the performance of every piece of equipment. Typically, we can measure the performance of a representative sample of the population and extrapolate the results to the whole. The process of identifying which and how many items to measure and evaluating the results to assess reliability is known as sampling.

Sampling is often used where the population of affected systems is too large to measure each point cost-effectively. The primary requirement for sampling to be effective is that the samples selected must be representative of the population as a whole.

Any end-use technology or building category can be evaluated using sampling techniques:
lighting upgrades, controls upgrades, window & split air conditioner replacements, package units, etc.

The primary advantage of sampling is cost-effectiveness. By measuring the performance of a sample of affected items rather than the entire population, the level of effort is significantly reduced.

The fundamental disadvantage of sampling is the introduction of uncertainty because not every item is measured. With careful sample plan development, selection, and evaluation,
uncertainty can be kept to minimal levels and be quantified. Please note that a sampled measurement process can be compromised if:

- **The selected samples are not representative of the population.**
- **Data collection problems reduce the sample size to less than acceptable numbers.**
- **There proves to be much greater variability in the population than originally assumed.**

These limitations may not be discovered until the data has been collected and evaluated, making corrective steps difficult.

Types of Sampling:

For most measurement and verification purposes, there are two types of sampling:

- **Simple random sampling draws representative samples from a single population where any sample is representative of the whole. One example is measuring the average power draw of several light fixtures containing two 4-foot T-8 lamps in order to establish the typical power draw where hundreds of identical fixtures exist.**
- **Stratified sampling is used where the population is not homogeneous and needs to be segregated by some defining characteristic. While the population could be divided into discrete groups and simple random sampling applied**

to each group, this would result in a greater overall sample size and level of effort. Stratified sampling considers the contribution to the overall uncertainty from each group (strata) and allocates the samples to minimize the overall uncertainty and sample size. An example might be sampling of split units as per size, age or application.

For sampling to be effective, samples must be drawn from a homogeneous population. Homogeneous in this context means that all members of the population have similar characteristics.

For most projects, it is reasonable to assume that a homogeneous population can be defined by a single average value and that most of the members will have values very close to that average. Only a few members will vary significantly from the average, with some having values higher and some lower than the average value. The farther from the average value, the fewer members will be found. This type of population is considered a normal distribution.

Definitions:

The coefficient of variation (CV) is a mathematical expression of the dispersion of a data set from its mean. It can be visualized as how wide or narrow the distribution (or bell curve) is when data is plotted on a two-dimensional graph. The CV is defined as the standard deviation divided by the average value (or mean) of that data set.

We would like a certain amount of confidence level in our measured results. If the desired

confidence level is 90%, then there is a 90% probability that the true value lies within the stated precision. Increasing the desired confidence level will increase surety but will require expending more effort and greater expense.

The purpose of a sampled measurement process is to quantify a value that represents the entire population. While the average value of the measured samples is known exactly, sampling introduces some uncertainty as to the true average value of the population. If we accept a 10% precision in our measurement, we are saying that the average value of the population is within ±10% of our measured value.

Confidence Level and Precision must be reported together – a specification of either one alone is meaningless. When reporting results, a statement of 10% precision at 90% confidence level means that: 1) the true value of the population is within 10% of the measured value; and 2) we are 90% certain of this result.

Sampling Process:

The following are the steps to be taken in a sampled measurement process:

1. Define the population - The first step in a sampled measurement process is to identify the population of interest. Usually, an equipment inventory is available that defines the population.

2. Decide if the population is homogenous or heterogeneous - Consider the population and decide if the members are homogeneous or heterogeneous. Do they all have identical characteristics or are there characteristics that identify members of the population as unique? Are all fan motors the same size, or do they span 2- to 50-hp? Do all 20-hp motors serve the same purpose, or are some fire pumps and others driving conveyer belts? If the population can be considered homogenous, then use simple random sampling. If the population is heterogeneous, then either divide the population into homogeneous groups and then use simple random sampling on each. Where the entire population is comprised of a number of distinct categories (strata), the population can be segregated into these categories or strata. Each stratum is then sampled as an independent sub-population, out of which individual elements can be randomly selected. Strata are selected by considering which categories might have the greatest influence on the primary outcome variable one wishes to measure.

3. Define the desired confidence level and precision – Typically, we may like to determine the true value with a ±10% precision at 90% confidence level. Where individual measurements are expensive or the populations have large variances (high CV), reducing the acceptable precision results in smaller sample sizes. Because precision is proportional to the square of the sample size, relaxing the precision from 10% to 20% results in a four-fold decrease in sample size. Increasing the precision from 10% to 5% requires a four-fold increase in sample size.

4. Assume an initial coefficient of variation (CV) - The sample size to achieve a specific precision and confidence depends on the population coefficient of variation CV. But the CV is often not known until after the measurements are taken, so the sample size cannot be determined in advance. To get around this paradox, we must assume a CV value in order to develop a sampling plan. If measurements have been performed previously and the CV is known for the parameter of interest, one can initially apply the CV determined by earlier research. When estimating the true CV, a statistician should use a default value for the CV of not less than 0.5 for homogeneous samples. However, the actual CV must be calculated afterwards and compared to the assumed value.

5. Calculate the initial sample size n0 - With the population defined and the precision and confidence targets set, calculate the required number of samples for each population or group. Where populations are small or the desired precision is very high, the calculated sample size may be close to or even exceed the population size. The sample size can be adjusted using the Finite Population Correction equation.

6. Select random samples - From the equipment list, select samples at random until the desired number have been identified. A quasi-random selection

process can be used, such as selecting every kth element. Alternatively, a random number generator can be used to select samples.

7. Implement the measurement process - Using randomly selected samples, take measurements. Occasionally, the identified items may not be able to be measured (equipment not functioning). While there may be a concern that substitutions can introduce bias, it is usually better to accept a substitute member than reduce sample size. If the populations are truly homogeneous, substitutions will not introduce bias.

8. Evaluate results - For each population or measurement group, calculate: the average value, the standard deviation, the coefficient of variation, and the size of the final sample. Compare the CV of each group – if the actual CV is less than the assumed value, then the desired precision and confidence targets have been met. For each group, calculate the actual precision achieved. If time and budget permit, additional measurements can be taken to increase the sample size and improve the precision. In all cases, report the actual precision achieved.

<u>Sampling Calculations:</u>

For each group, the parameter to be measured needs to be identified, the population size known, and the relative variance of the parameter estimated.

Sample size formula is:

$$n_0 = \left(\frac{Z \cdot CV_{\%}}{e_{\%}}\right)^2$$

Where,

- n_0 is the initial sample size

- Z is the coverage factor based on desired confidence level referred from t-table
- $CV_{\%}$ is the coefficient of variation, standard deviation divided by the mean
- $e_{\%}$ is the desired level of relative precision

Example - If the desired confidence level is 90%, desired relative precision is ±10% and estimated CV is 0.5, the calculated initial sample size will be

$$n_0 = \left(\frac{1.645 \cdot 0.5}{0.10}\right)^2 = 67.7$$

The value of n must be an integer. The calculated value should be rounded up to the nearest integer value (e.g., 67.7 becomes 68).

Finite Population Adjustment - The necessary sample size can be reduced if the entire population being sampled is no more than 20 times the size of the sample. This adjustment reduces the sample size (nred) as follows:

$$n_{red} = \frac{n_0 \, N}{n_0 + N}$$

Because the initial sample size no is determined using an assumed CV, it is critical to remember that the actual CV of the population being sampled may be different. Therefore, a different actual sample size may be needed to meet the precision criterion. As sampling continues, the mean and standard deviation of the readings should be computed. The actual CV and required sample size should be recomputed. This re-computation may allow early curtailment of the sampling process. It may also lead to a requirement to conduct more sampling than originally planned. To maintain M&V costs within the budget, it may be appropriate to establish a maximum sample size. If this maximum is reached, the saving report(s) should note the actual precision achieved by the sampling.

<u>Case Study – Sampling:</u>

Situation - A knitting mill in a southern Asian country operates 2 shifts per day. There was a standing order for the supervisors to turn off all lights in each zone at the end of the second shift. There are 70 light switches. Supervisors regularly changed between working on the first and second shifts. They habitually forgot their duty to turn off lights.

The plant manager undertook a project to modify the lighting so that occupancy sensors turned the lights on and off. He wanted to document the results to show the supervisors how poorly they had been using the light switches.

Factors Affecting M&V Design - None of the production area had windows or skylights. It is neither heated nor cooled. Lighting circuits are integrated with other electrical loads so that lighting use could not be easily isolated from other uses of electricity.

The plant manager did not wish to spend a lot to determine saving, but needed a credible
statement of the saving.

M&V Plan - To minimize M&V costs it was decided to perform saving measurements for only a short representative period and use IPMVP Option A. Since the primary purpose of the retrofit was to control production area lighting hours, a sampling-based method was developed to measure the change in operating hours. The lighting power was estimated from manufacturers' ratings.

Lighting loggers were placed randomly around the production area to record the operating hours of randomly chosen lighting zones. The number of loggers was chosen as follows, to obtain an overall precision in operating period estimates of ±10% @ at 95% confidence level. It was estimated that the mean operating hours before installation of the occupancy sensors would be 125 hours per week, and that the standard deviation in readings would be 25. Therefore, the initially estimated CV is 0.20 and the necessary number of samples (with Z of 1.96) will be 15.

It was assumed that after installation of occupancy sensors the CV will be much lower so the 15 loggers will be adequate.

There are no interactive effects of this retrofit on other building loads because the plant is neither heated nor air-conditioned. The reduction in night-time lighting is expected to make the building more thermally comfortable at the beginning of the morning shift.

Results - After a one-month period, data was gathered from the loggers and the average weekly operating hours computed for the 15 zones. The mean value was 115 and the standard deviation was 29. Therefore, the CV was 0.24 (= 29/115), higher than the expected value and worse than necessary to meet the precision requirement. Therefore, another month of recording was undertaken. Then the mean of the eight weeks of average weekly values was 118, and the standard deviation was 24 (CV=0.20). This was deemed an adequate measurement of operating hours in the baseline period, with no occupancy sensors.

The occupancy sensor controls were installed after the above baseline test. Operating hours were again logged in the same locations for a month. The mean was found to be 82 hours per week, and the standard deviation was 3 hours. In this situation, the CV is 0.04 and well within the required 0.2, so the one-month readings were considered adequate.

ANNEX E

Instrumentation and Modeling for Retrofit Isolation

Description:

The type of load and type of retrofit affects instrumentation and modeling requirements. Loads can be classified according to whether the load is fixed or variable or whether the use is constant or variable. This classification makes a distinction between constant or varying loads (i.e., different rates at which the system uses energy) versus constant or varying uses (i.e., different rates at which the system is used) primarily for purposes of measurement. This results in the following four classifications:

- Constant load, constant use (CL/TS)
- Constant load, variable use (CL/VS)
- Variable load, constant use (VL/TS)
- Variable load, variable use (VL/VS)

The load is either constant or variable, and the schedule is either known or unknown/variable. The retrofit may change the magnitude of the load and/or change it to/from a constant load from/to a variable load. The retrofit may also change the schedule.

For conversion of a constant load to a varying load, such as photocell dimming controls installed on manually controlled indoor light fixtures, it is necessary to measure preinstallation kilowatts and install a kilowatt-hour meter and run-time meter on the line side of the dimmer. Saving are calculated by multiplying the measured circuit full-load kilowatts by the operating hours from the run-time meter minus the kilowatt-hours measured at the dimmer.

For variable load changed to higher efficiency variable load, such as converting a VAV system using inlet vanes to a variable-speed drive (VSD) on the fan motors, an energy indexing method can be used. This is done by measuring preinstallation kilowatts of the fan at several flow rates to determine the baseline power flow relationship. After installation, measure the variable-speed-drive power and flow rates to determine the new power-flow relationship. By recording the flow rates for a representative post retrofit period, the saving are calculated as a function of flow by the differences in the kilowatts or cubic feet per minute (cfm) values times the hours of flow at representative flow levels.

<u>Load</u>

1. Constant load—it must be known that under no circumstances could the load (kW or kVA) have varied by more than ±5% for that full year of operation or some other percentage considered as acceptable to the client. Loads with a predictable use profile that result in constant energy use over a known period (work week, weekend, etc.) can be treated as constant loads.
2. Variable Load - Variable load, includes any conditions that are not satisfied or expressed in the previous paragraph.

<u>Schedule</u>

1. Known on/off time schedule - must be known so the total hours of operation can be calculated based on the scheduled settings without any run-time measurements (e.g., controlled by a time clock or emergency management control system or always on).
2. Unknown/variable schedule, including randomly turned on/off; controlled by occupancy sensor, temperature, or on time clock but often manually overridden.
3. One-time load measurement: the load has to have been measured at least once, more if necessary to prove that load is a "constant" load (i.e., does not vary by more than ±5%).

Sufficient measurement of run time: continuous measurement of run time, unless it can be shown that sufficient data have been measured in that year to predict what the run time would have been for that full year of operation.

Sufficient load measurements to characterize the load: continuous measurement of the load, unless it can be shown that sufficient data have been measured in that year to predict what the energy use and coincident demand would have been for that full year of operation. If the pre-retrofit load is variable, one needs to have sufficient information on what controls the variation in the load before the retrofit to develop a model to predict what the energy use and coincident demand would have been had the retrofit not taken place. This also would require sufficient information for the post-retrofit period to apply the model for that time period.

There are numerous possible combinations of before and after retrofit load classifications. Below table from ASHRAE Guideline 14 summarizes the possible combinations and lists the metering requirements for each combination.

Preretrofit	Retrofit Changes	Required Metering	
		Preretrofit	Postretrofit
CL/TS	Load but still CL	One-time load measurement	One-time load measurement
CL/TS	Load to VL	One-time load measurement	Sufficient load measurements to characterize load
CL/TS	Schedule but still TS	One-time load measurement (either pre- or postretrofit)	
CL/TS	Schedule to VS	One-time load measurement (either pre- or postretrofit)	Sufficient measurement of run time
CL/TS	Load but still CL and schedule but still TS	One-time load measurement	One-time load measurement
CL/TS	Load to VL and schedule but still TS	One-time load measurement	Sufficient load measurements to characterize load
CL/TS	Load but still CL and schedule to VS	One-time load measurement	One-time load measurement and sufficient measurement of run time
CL/TS	Load to VL and schedule to VS	One-time load measurement	Sufficient load measurements to characterize load
CL/VS	Load but still CL	One-time load measurement and sufficient measurement of run time	One-time load measurement and sufficient measurement of run time
CL/VS	Load to VL	One-time load measurement and sufficient measurement of run time	Sufficient load measurements to characterize load
CL/VS	Schedule to TS	One-time load measurement (either pre- or postretrofit) and sufficient measurement of run time	
CL/VS	Schedule but still VS	One-time load measurement (either pre- or postretrofit) and sufficient measurement of run time	Sufficient measurement of run time
CL/VS	Load but still CL and schedule to TS	One-time load measurement and sufficient measurement of run time	One-time load measurement
CL/VS	Load to VL and schedule but still TS	One-time load measurement and sufficient measurement of run time	Sufficient load measurements to characterize load
CL/VS	Load but still CL and schedule to VS	One-time load measurement and sufficient measurement of run time	One-time load measurement and sufficient measurement of run time
CL/VS	Load to VL and schedule but still VS	One-time load measurement and sufficient measurement of run time	Sufficient load measurements to characterize load
VL/TS or VS	Load to CL	Sufficient load measurements to characterize load	One-time load measurement and sufficient measurement of run time
VL/TS or VS	Load but still VL	Sufficient load measurements to characterize load	Sufficient load measurements to characterize load
VL/TS or VS	Schedule still or to TS	Sufficient load measurements to characterize load	Sufficient load measurements to characterize load
VL/TS or VS	Schedule to or still VS	Sufficient load measurements to characterize load	Sufficient load measurements to characterize load
VL/TS or VS	Load to CL and schedule still or to TS	Sufficient load measurements to characterize load	One-time load measurement
VL/TS or VS	Load but still VL and schedule still or to TS	Sufficient load measurements to characterize load	Sufficient load measurements to characterize load
VL/TS or VS	Load to CL and schedule to or still VS	Sufficient load measurements to characterize load	One-time load measurement and sufficient measurement of run time
VL/TS or VS	Load but still VL and schedule to or still VS	Sufficient load measurements to characterize load	Sufficient load measurements to characterize load

Figure 16 Metering Requirements for each Combination.