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Sri Lanka
Volume I

Industrial/Commercial Sectors
Concepts and Options for Determining Energy Savings
(Adapted from IPMVP-2002 & Indian M&V protocols)

Nexant

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PERFORMANCE MONITORING & VERIFICATION PROTOCOLS/GUIDELINES
INDUSTRIAL/COMMERCIAL SECTORS
CONCEPTS AND OPTIONS FOR DETERMINING ENERGY SAVINGS
(ADAPTED FROM IPMVP-2000 & INDIAN M&V PROTOCOLS)
SRI LANKA

For

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Nexant SARI/Energy

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Ronald Comester

Ceylon Electricity Board

Gamini Senanayake

Industrial Services Bureau

Dammika Nanayakkara

LTL Energy

G.T. Fernando

Sri Lanka Energy Managers Association

Gemunu Ranasinghe

Ceylon Electricity Board

Harsha Wickramasinhe

Energy Conservation Fund

E. M. Piyasena

Sri Lanka Energy Managers Association

Anura Vidanagamage

Industrial Services Bureau

S. Ganegoda

LTL Energy

Prabatha Wickramasinghe
Hayleys Engineering Services Ltd.

Sarath Doranegoda
National Development Bank

Piyal Hennayake
Hatton National Bank

M. A. J. Fernando
Commercial Bank of Ceylon

H.A. Wimal Nadeera
Energy Conservation Fund

N.C.D.S.C. Gunasekera
DFCC Bank

Gyanendra Lal Pradhan
ESCO Nepal P. Ltd

Subhash Shrestha
ESCO Nepal P. Ltd

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PREFACE

Purpose and Scope

The purpose of this protocol is to set out the framework and operational aspects of independently verifying energy savings and benefits from energy-efficiency projects and energy-service company (ESCO) contracts, applicable for industrial and commercial sectors. The aim is to enable ESCOs, end-users, financial institutions and consultants to speak with one voice. The protocol eventually will also help in funding of such projects by financial institutions by taking advantage of "emission trading."

Energy conservation measures covered herein include fuel- and electricity-saving measures, through installation or retrofit of equipment, and/or modification of operating procedures of available equipment and control systems.

This protocol is intended to be fuel neutral and can be applied to a broad range of applications. Essentially, for an ESCO contract, this document can help in selecting a measurement and verification (M&V) approach that is most appropriate for the project,taking into account the project costs, technology-specific requirements, and risk assessment.

This protocol is not intended to prescribe contractual terms between buyers and sellers of efficiency services, although it provides guidance on some of these issues. Once other contractual issues are decided, this document can help in the selection of the M&V approach that best matches project costs and savings magnitude, technology-specific requirements, and risk allocation between buyer and seller, i.e., which party is responsible for installed equipment performance and which party is responsible for achieving long-term energy savings.

The IPMVP 2000 and the Indian M&V protocols 2000 approach are found to be applicable to M&V of savings for energy-efficiency projects in the Sri Lankan scenario too. However, we need to make base-line adjustments for factors such as capacity utilization, throughput, power cuts, and interruptions. Option D's applicability in industry may not be wide as software packages covering specific manufacturing processes may not be readily available.

Structure of Sri Lanka-Specific Protocol

This protocol is based on the International Performance Measurement and Verification Protocol (IPMVP) 2000 and the Indian M&V protocols. The IPMVP is quite generic in nature and an effort has been made to provide specific approaches in this protocol.

This addresses the typical energy conservation measures (ECMs) in the Sri Lankan Industrial and commercial sectors in addition to the overview of the best practices available in the IPMVP and the Indian M&V protocols.

Some things that make Sri Lanka unique include relatively constant annual weather conditions, a single electric utility company (Ceylon Electricity Board), an evolving ESCO and financial industry, and significant opportunity for energy-efficient new construction.

Moving Forward & Future Work

The future work is in terms of adding more specific and elaborate case examples for each of the options as in the case of IPMVP and the Indian M&V protocols. A core group is to be formed on the *egroups*URL, who will be constantly providing feedback on discussions of the need for a Sri Lanka-specific protocol and technical and financial issues. This approach should be extended so that more members can get involved and share their experiences. This would enable constant improvement and updating of the protocol periodically, taking into account the developments that take place.

End-users and financial institutions need to be constantly kept informed as they are the major stakeholders in such energy-efficiency projects (apart from the ESCOs). Systems should be worked out for third-party M&V contractors and utilizing emission trading for funding energy-efficiency projects.

The next version could be the development of a number of examples under the Sri Lankan scenario of the popular ECMs on the lines presented in Appendix A of the IPMVP 2000. This would go a long way to ensuring adequate comfort for funders (external) and internal (within the corporation) as well as the end-users.

Chapter 1 Introduction

1.1 Background

In Sri Lanka, about **60%** of the population has access to electricity with an installed capacity of about 2,000 MW (2 GW), of which around **60%** is hydropower and the rest is thermal (oil based). Heavy dependence on hydropower, with the demand for electricity increasing at around **8%** per annum, caused power shortages during drought periods in 1996, 1998, and 2001, affecting industry and the economy as a whole.

With almost all economically viable hydro resources now developed, the emphasis is now on the addition of thermal power to meet the increasing demand for energy from both the domestic and industrial sectors. However, increased electricity costs as a result of large additions of oil-based thermal generation to the electricity grid have affected the industrial output.

In order to mitigate the impact of high electricity tariffs and the possible environmental impact from increased thermal generation, energy conservation/efficiency is promoted aggressively in Sri Lanka, with a **30%** to **40%** energy-saving potential in industry from cost-effective end-use improvements.

The importance of energy conservation/efficiency has been recognized in Sri Lanka, but barriers such as lack of policy, knowledge, technology availability, and concessionary funding have hindered the widespread commercialization and large-scale implementation of end-use energy-efficiency improvements.

In this context, an important step has been taken by the United States Agency for International Development (USAID) under the technical assistance component of the South Asian Regional Initiative for Energy (SARI/Energy) to develop mechanisms to promote end-use efficiency and conservation in industry.

1.2 SARI/Energy Objectives

South Asian Regional Initiative for Energy (SARI/Energy) aims at promoting mutually beneficial energy linkages among the participating nations. A key component of this is the promotion and development of Energy Service Company (ESCO) activities in the region to reduce energy costs to industry.

The components of ESCO development activities under SARI/Energy are:

- Business development & financing
- Introduction to monitoring and verification protocols
- Certification and training of energy auditors
- Development of a financing mechanism for ESCOs
- Establishment of a South Asia network of ESCOs

1.3 Markets Component — M&V protocol

Considerable opportunities exist for improving energy efficiency in every sector of the Sri Lankan economy. Actual investments being made today are but a small fraction of the economically attractive investments available. One of the barriers to increased investment is the lack of consistent and objective procedures and guidelines for quantifying energy savings. Measurement and verification protocols establish a common framework and define acceptable procedures for determining savings from energy-efficiency and energy conservation projects. Formally adopting a standard M&V protocol will result in more reliable energy saving estimates and improve lender confidence for securing lower cost financing for energy-efficiency projects.

In this light, efforts were made to develop Sri Lanka-specific M&V protocols, based on the International Performance Measurement and Verification Protocol (IPMVP) and the Indian M&V protocol, for independently verifying energy savings and energy cost savings in ESCO contracts.

1.4 ESCOs

Energy service companies (ESCOs) develop and implement energy-efficiency projects that support themselves financially based upon the measured and verified savings that these projects generate. ESCOs often guarantee the savings to be realized and typically an agreed percentage of the savings is paid by the client to the ESCO to cover the cost of the services while simultaneously leading to positive cash flows for the client. This service from ESCOs is often termed "performance contracting."

Although end users of energy are overwhelmed by the ESCO concept, they are not clear as to how to go about such projects in the absence of any standards for measuring and verifying savings. Surveys indicate that energy-efficiency projects with good measurement and verification result in increased and consistent energy savings. The importance of M&V protocol therefore becomes clear against in this background.

1.5 Role of Protocol

The protocol sets out the framework and operational aspects of independently verifying energy savings and benefits for ESCO contracts in Sri Lanka, applicable for industrial and commercial sectors. The protocol:

- Is based on the International Performance Measurement and Verification Protocol (IPMVP) and the Indian M&V protocols and is modeled along the lines of the U.S. Federal Energy Management Program (FEMP) document.
- Provides all stakeholders a common set of terms to discuss key M&V project-related issues and establishes methods that can be used in energy performance contracts.
- Defines broad techniques for determining savings from both a "whole facility" and an individual technology.
- Applies to a variety of facilities, including commercial, institutional, and industrial buildings and industrial processes.
- Provides an outline of procedures that can be applied to similar projects throughout all geographical regions and that are internationally accepted, impartial,and reliable.
- Presents procedures, with varying levels of accuracy and cost, for measuring and/or verifying baseline and project installation conditions, and long-term energy savings.
- Provides a comprehensive approach to ensuring that quality issues are addressed in all phases of ECM design, implementation, and maintenance.
- Creates a living document that includes a set of methodologies and procedures that enable the document to evolve over time.
- Is fuel neutral — the goal is to verify cost savings.

- Does not dictate approach—this protocol is intended as a guideline for measurement and verification in energy-efficiency projects and is essentially a tool to help ESCOs prepare an M&V plan that adheres to international standards.
- Is intended for a broad range of applications across all the sectors of the economy, viz., industrial and commercial; i.e., it is neither process- nor technology-specific.

1.6 Audience for Protocol

The target audience for this protocol includes:

- ESCOs (energy service companies)
- Financial institutions
- Consultants
- Project developers
- Researchers
- Energy managers
- Industry and other relevant associations
- Government agencies, and
- Endusers of ECMs

1.7 Uses of Protocol

This protocol will enable all stakeholders, i.e. ESCOs, end-users, financial institutions, and consultants to speak with one voice and thereby minimize disputes in the measurement & verification of savings. Eventually, it will render funding by financial institutions much faster and easier. Financial institutions will be able to make use of "emission trading" for funding such energy-saving projects.

2.1 Introduction

This chapter discusses how measurement and verification relate to energy-efficiency projects. Performance contracting projects are unique because the seller cannot absolutely quantify the value of the product to be delivered, in this case the reduction in utility costs and secondary performance benefits. Measurement and verification are an essential component to this business arrangement in order to satisfy the customer and the financier that the promised benefits have been delivered.

2.2 Contract Types

The primary concept in performance contracting is that an energy service company (ESCO) can make changes at a customer's facility that will reduce total energy costs as well as provide secondary benefits such as improving equipment operation. The customer then pays the ESCO from the savings realized in the utility bills. Unlike a design/build project, the customer benefits from not having to make a capital investment and from having some reassurance that the promised savings will materialize. Key to the success of this arrangement is that the ESCO, customer, and financier have confidence that the project is performing as promised and that the expected savings are being realized.

There are several ways that performance contracting arrangements can be structured. These include:

- Guaranteed savings: The ESCO offers design and construction services to the customer. Performance is assured by guaranteeing that savings will meet a particular threshold. If the savings do not materialize, payments to the ESCO are withheld until the project performs satisfactorily.
- Shared savings: The ESCO and the customer agree to share the savings for a set period of time. The greater the savings, the more the ESCO and the customer benefit. If savings do not materialize, the ESCO receives no payment.
- Vendor financing: Some equipment manufacturers provide ESCO services in order to sell their own equipment. Financing is usually "pay from savings"; guarantees may or may not be available.

There are variations on all of these arrangements, but these cover the fundamental types of business deals. The guaranteed savings model is the most commonly used today; shared savings projects have declined in popularity.

2.2.1 Guaranteed Savings Contracts

The ESCO evaluates a facility and designs a project. The ESCO may be the contractor or may arrange for others to do the work. The customer obtains financing through a third party with the ESCO guaranteeing the savings (and thus the ability to repay the debt). Payments are fixed over the contract term.

Measurement and verification is necessary to demonstrate that the savings have met a particular threshold, but the actual level of savings does not need to be determined. Long-term savings verification is dependent on the specific contract, with some contracts only requiring a single demonstration that the savings guarantee has been met. Guarantees are enforced by having the ESCO assume obligation for debt repayment in the event that savings do not materialize.

2.2.2 Shared Savings

The ESCO designs a project and proposes to finance and construct it. The ESCO may be the contractor or may arrange for others to do the work. The ESCO obtains financing through a third party. Measurement and verification is necessary to determine the actual savings, which are then split between the ESCO and the customer. Payments therefore fluctuate during the contract term.

The ESCO assumes the debt and repayment risk, increasing the cost of capital. Measurement & verification plays a critical role in the project financing and needs to be performed during the contract term.

2.2.3 Vendor Financing

An equipment vendor acts as an ESCO by providing design and construction services as well as project financing. The customer "pays from savings," which may or may not be guaranteed. If savings are not guaranteed, the arrangement more closely resembles a design/build or lease/purchase contract. Measurement and verification activities are commensurate with the savings guarantee. Projects are typically limited to those where the vendor's equipment is a major component of the project.

2.3 Role of M & V in Performance Contracting

Performance contracting is unique in the business world because services are sold without being able to specify them beforehand. Only after a project is installed can its benefits be evaluated. However, evaluating the benefits is made difficult by the fact that *savings cannot be directly measured*. This means that even after a project is installed the benefits cannot be determined with absolute certainty.

The purpose of measurement and verification is to quantify a project's benefits to assure all parties that they exist. There will always be some uncertainty surrounding the claimed savings, but a properly executed M&V effort will reduce that uncertainty to acceptable levels without imposing unreasonable project costs.

Selection of an M&V approach requires balancing precision (minimizing uncertainty) with costs. Additionally, responsibilities for changing usage and performance factors need to be allocated so that the party responsible for changes to a project is the party that bears the responsibility for them. Measurement and verification therefore serves two purposes in a performance contract; it

1. Minimizes risk by reducing uncertainty and
2. Allocates risk to the responsible party

2.4 Performance Contracting Risks

Performance contracting involves elements of risk due primarily to the nature of the arrangement between the ESCO and the customer. The ESCO promises to deliver lower utility costs to the customer through technical and operational changes, but cannot state with absolute certainty what those benefits will be beforehand. Other project risks are common to any business deal involving capital improvements, construction, and financing. One should keep in mind that there is also the risk of taking no action: declining an opportunity to participate in an energy-efficiency project represents lost opportunity, the inability to realize any savings or capital improvement, and increased exposure to rising energy prices.

The types of performance contracting risk can be broadly categorized into the following areas:

- Financial
- Operational
- Performance

Of these, measurement and verification can be used to mitigate the second two risks (operational and performance). Financial risks are not readily addressed through M&V but are nonetheless present in performance contracting. A good business contract will describe how each issue will be addressed and by whom. Each of the following risks types can be further broken down and described as follows.[1]

2.4.1 Financial

Interest rates: Neither the ESCO nor the customer has significant control over the prevailing interest rate. During the project development interest rates will change with market conditions. Higher interest rates will increase project cost, finance term, or both. The timing of the contract signing may affect the available interest rate and project cost. Clarify penalties for total or partial payoff of the project or project financing.

Energy prices: Neither the ESCO nor the customer has significant control over actual energy prices. For calculating savings, the value of the saved energy may be held constant, change at a fixed inflation rate, or float with market conditions. Calculated savings based on stipulated energy prices may be higher or lower than actual savings depending on actual (future) energy costs. Clarify what energy price assumptions will be used for calculating savings.

Construction costs: The ESCO is responsible for determining construction costs and defining a budget. In a fixed-price design/build contract, the customer assumes little responsibility for cost overruns. However, if construction estimates are significantly greater than originally assumed, the ESCO may find that the project or measure is no longer viable and drop it. In any design/build contract the customer loses some design control. Clarify design standards and the design approval process (including changes), and how costs will be reviewed. Clarify what internal and external reviews should be made and by whom.

Measurement & Verification: The customer assumes the financial responsibility for M&V costs directly or indirectly through the ESCO. If the customer wishes to reduce project cost, it may do so by accepting less rigorous M&V activities with more uncertainty in the savings estimates. Clarify what performance is being guaranteed (equipment performance, operational factors, energy cost savings), and that the M&V plan is robust enough to verify it. Clarify the reasonableness, validity, and limitations of any M&V models. Document the basis of all stipulated values.

Avoided costs: The customer and the ESCO may agree that the project includes savings from recurring and/or one-time energy-related cost savings. This may include one-time savings from avoided capital expenditures for projects that were planned and budgeted but will no longer be necessary. Operations and maintenance (O&M) savings may result from reduced parts and labor costs. However, O&M savings need to be based on actual budget and spending patterns, even if that amount was insufficient to properly maintain a system. Clarify sources of cost savings and whether cost savings are one-time or recurring.

[1] Adapted from the US Federal Energy Management Program's Responsibility Matrix for Federal Performance Contracts.

Delays: Both the ESCO and the customer can cause delays. Failure to implement a viable project in a timely manner costs the customer unrealized savings and can add cost to the project (e.g. inflation, construction interest, re-mobilization). Clarify the project schedule and how delays will be handled.

Major changes in facility: The customer controls major changes in facility use, including closure. If a facility is closed or experiences major changes in business, the realized savings may vary significantly. Clarify responsibilities in the event of a premature facility closure (total or partial), loss of business, or other major changes.

2.4.2 Operational

Operating hours: The customer generally has control over the operating hours. Increases and decreases in operating hours can show up as increases or decreases in "savings" depending on the M&V method (e.g., operating hours times improved efficiency of equipment vs. whole building utility analysis). If the operating hours are stipulated, the baseline should be carefully documented and agreed to by both parties. Clarify if operating hours are to be measured or stipulated, and what the effect on savings will be if they change.

Load: Equipment loads can change over time. The customer generally has control over hours of operation, conditioned floor area, intensity of use (e.g. changes in occupancy or level of automation). Changes in load can show up as increases or decreases in "savings" depending on the M&V method. If the equipment loads are stipulated, the baseline should be carefully documented and agreed to by both parties. Clarify if equipment loads are to be measured or stipulated and what the effect on savings will be if they change.

Weather: Many energy-efficiency measures are affected by weather. Neither the ESCO nor the customer has control over the weather. Changes in weather can increase or decrease savings depending on the M&V method (e.g., equipment run hours times efficiency improvement vs. whole building utility analysis). If weather is normalized, actual savings could be less than payments for a given year, but they will"average out" over the long run. Weather corrections to the baseline or ongoing performance should be clearly specified and understood.

User participation: Many energy conservation measures require user (customer) participation to generate savings (e.g., control settings). Without a clear description of how savings will be realized and who will be responsible for maintaining user participation, ESCOs may be unwilling to invest in these measures. If performance is stipulated, document and review assumptions carefully, and consider how M&V will confirm the capacity to save (e.g., confirm that the controls are functional). Clarify how savings will be realized and who will be responsible for maintaining user participation.

2.4.3 Performance

Initial equipment performance: Generally, the ESCO has control over the selection of equipment and is responsible for its proper installation, commissioning, and initial performance. The ESCO usually has responsibility to demonstrate that the new improvements meet expected performance levels, including specified equipment capacity, standards of service, and efficiency. Clarify who is responsible for initial performance, how will it be verified, and what will be done if performance does not meet expectations.

Long-term equipment performance: Initial equipment performance is controlled by the ESCO. However, if the customer retains some or all of the maintenance responsibility (including scheduled and unscheduled maintenance, repairs, and replacements as necessary), the ESCO could lose control of performance. Clarify who is responsible for long-term performance, how will it be verified, and what will be done if performance does not meet expectations.

Operation: Responsibility for operation is negotiable and can affect performance. Clarify how proper operation will be assured. Clarify responsibility for operations and the implications of equipment control.

Maintenance & repair: Responsibility for maintenance and repair is negotiable; however, it is often tied to performance. Clarify how long-term maintenance and repair will be ensured, especially if the party responsible for long-term performance is not responsible for maintenance. Clarify who is responsible for equipment overhaul and for component or equipment repair required to maintain operational performance throughout the contract term. Special attention is required if the customer outsources maintenance. Clarify what will happen if equipment performance is affected by poor maintenance and repair.

Equipment Replacement: Responsibility for replacement of contractor-installed equipment is negotiable; however, it is often tied to equipment performance. Clarify who is responsible for replacement of failed components or equipment throughout the term of the contract. Specifically address potential impacts on performance due to equipment failure. Life of equipment is critical to performance during the contract term. Clarify life expected and warranties for all installed equipment.

Conduct periodic M&V activities as specified in the chosen Option to (a) verify the operation of the installed equipmentand systems, (b) determine current-year savings, and (c) estimate savings for subsequent years.

2.5 M&V ACTIVITIES

Measurement and verification activities are defined by a project-specific M&V plan. The plan describes how project performance will be evaluated and by whom. Developing an M&V plan is an inherent part of the energy-efficiency project, not an add-on item. Implementing the activities defined in the plan are essential to the project's ultimate success and customer satisfaction.

The purpose of these protocols is to define the elements of a successful M&V plan and to assist the ESCO and customer in developing a plan that meets the needs of all parties. Developing an M&V plan is a cooperative effort between the ESCO and the customer (and possibly the financier). Results from the M&V efforts shouldaddress the customer's and the ESCO's risks while remaining cost effective.

Table 2-1 lists in rough chronological order the steps needed to develop an M&V plan along with an energy-efficiency project. The customer needs to be involved in the project as an integral partner by providing relevant information and feedback on proposed activities. The ESCO needs to treat the customer as a partner and consider their requests and desires.

Table 2-1: M&V Plan Development

Project Phase	Customer	ESCO
Initial Proposal	▪ Provide information to ESCO ▪ Evaluate M&V approach	▪ Develop M&V Approach ▪ Develop savings estimates
Project Development	▪ Evaluate M&V plan	▪ Develop M&V plan ▪ Take baseline measurements ▪ Revise savings estimates
	Sign Contract	
Construction	▪ Approve and accept project	▪ Install project ▪ Take new measurements ▪ Verify initial performance
Performance Period	▪ Approve claimed savings values ▪ Pay ESCO	▪ Verify savings ▪ Submit M&V report and invoice

The roles of each party in these steps are described in the contract, depending on the type of specific business agreements, risk allocation, and accuracy of desired verification. In general, however, the ESCO provides documentation on equipment and demonstrated savings.

Documents submitted to the customer include the project pre-installation report, project post-installation report, and regular interval reports. These steps should apply to most projects; however, some M&V activities might not be necessary if certain variables, used in estimating savings, are stipulated in the contract. The steps identified above are briefly described in the following paragraphs.

A project-specific M&V plan that is based on these M&V Guidelines should be defined. This M&V plan will consider the type of project proposed, the desired level of confidence, and the level of accuracy of verification needed. The ESCO will propose a site-specific plan to be finalized either before or after execution of a contract or delivery order.

The M&V plan should include a project description, facility equipment inventories, descriptions of the proposed measures, energy- and cost-savings estimates, budget documentation (construction and M&V budgets), and proposed construction and M&V schedules. After the M&V plan is finalized, baseline documentation and analysis is conducted and project installation proceeds. Pre-installation metering is conducted in accordance with the site-specific M&V plan. Once the pre-installation metering and analysis is completed and approved by both parties, the project can be installed.

After the measures are installed and commissioned, the expected first-year energy-savings are estimated and documented in the post-installation report. It does not replace the first-year M&V report.

3.1 Basic Concept

Facility energy savings are determined by comparing the energy use before and after the installation of energy conservation measures. The “before” case is called the baseline; the “after” case is referred to as the post-installation or performance period. Proper determination of savings includes adjusting for changes that affect energy use but that are not caused by the conservation measures. Such adjustments may account for differences in weather, addition of loads, throughput, product mix, raw material changes, number of shift operation changes and occupancy conditions between the baseline and performance periods. In general,

Equation (1)

Savings = Baseline Energy Use – Post-Installation Energy Use ± Adjustments

Baseline and post-installation energy use can be determined using the methods associated with several different M&V approaches. These approaches are termed M&V Options A, B, C, and D. A range of options is available to provide suitable techniques for a variety of applications. How one chooses and tailors a specific option is based on the level of M&V rigor required to obtain the desired accuracy level in the savings determination and is dependent on the complexity of the ECM, the potential for changes in performance, and the savings value.

The adjustments term in Equation (1) can be of two different types:

- **Routine:** Adjustments for changes in parameters that can be expected to happen throughout the post-retrofit period and for which a relationship with energy use/demand can be identified. These changes are often seasonal or cyclical, such as weather or occupancy variations. This protocol defines four basic Options for deriving routine adjustments.
- **Non-Routine:** Adjustments for changes in parameters that cannot be predicted and for which a significant impact on energy use/demand is expected. Non-routine adjustments should be based on known and agreed changes to the facility.

The purpose of quantifying the energy savings in Equation 1 is to determine the cost savings to the customer. Energy savings alone do not justify a project; the customer must realize cost savings for a project to be economically viable. The cost savings are the difference between the customer’s utility costs before the project and what they pay after. In general,

Equation (2)

$$\text{Cost Savings} = (\text{Energy Rate}_{\text{Baseline}})(\text{Baseline Energy Use}_{\text{(adjusted)}}) - (\text{Energy Rate}_{\text{Post-Retrofit}})(\text{Post-Installation Energy Use} \pm \text{Adjustments})$$

Energy rates in Equation 2 are different for the baseline case and the post-retrofit case to account for potential changes in utility rate schedules (e.g., flat rate to time-of-day) or fuel switching (e.g., electricity to oil or oil to solar).

To minimize uncertainty in long-term projects, the baseline and post-retrofit energy rates should be specified in the contract. Allowing the baseline energy rate to fluctuate with market conditions means that the cost savings will likewise fluctuate, a situation that may affect project financing.

3.2 Methods

In the context of verifying energy savings, 'energy' refers to all commodities and their associated costs: electricity, fuel oil, natural gas, firewood, or other. Energy use quantities can be "measured" by one or more of the following techniques:

- Utility or fuel supplier invoices or meter readings
- Special meters isolating a retrofit or portion of a facility from the rest of the facility. Measurements may be periodic for short intervals, or continuous throughout the post-retrofit period
- Separate measurements of parameters used in computing energy use. For example, equipment operating parameters of electrical load and operating hours can be measured separately and factored together to compute the equipment's energy use
- Computer simulation that is calibrated to some actual performance data for the system or facility being modeled
- Agreed assumptions or stipulations of ECM parameters that are well known. The boundaries of the savings determination, the responsibilities of the parties involved in project implementation, and the significance of possible assumption error will determine where assumptions can reasonably replace actual measurement. For example, in an ECM involving the installation of more efficient light fixtures without changing lighting periods, savings can be determined by simply metering the lighting circuit power draw before and after retrofit while assuming the circuit operates for an agreed period of time. This example involves stipulation of operating periods, while equipment performance is measured.

The different M&V approaches are primarily differentiated by where the energy use "boundary line" is drawn. If only the measure being implemented is being evaluated independent of other energy-using systems, the approach is considered *retrofit isolation*. If the performance of a measure or a number of measures affects an entire facility and the total energy consumption is evaluated, the approach is considered *whole facility*. These two approaches are further divided according to the level of rigor and type of analysis used. These various approaches are given letter names as follows:

Retrofit Isolation Methods

Option A — Partially measured or one time measurement

Option B — Longer or continuous measurement

Whole Facility Methods

Option C — Whole facility energy analysis

Option D — Computer simulation

Table 3-1: Summary of M&V – Options, Savings Calculations & Applications

M&V Option	How Savings Are Calculated	Typical Applications
A. Partially Measured Retrofit Isolation Savings are determined by partial field measurement of the energy use of the system(s) to which an ECM was applied, separate from the energy use of the rest of the facility. Measurements may be either short-term or continuous. Partial measurement means that some but not all parameter(s) may be stipulated, if the total impact of possible stipulation error(s) is not significant to the resultant savings. Careful review of ECM design and installation will ensure that stipulated values fairly represent the probable actual value. Stipulations should be shown in the M&V plan along with analysis of the significance of the error they may introduce.	Engineering calculations using shortterm or continuous post-retrofit measurements and stipulations.	Any end-use efficiency improvement which has savings of less than **20%** energy reduction on the total bill and that have no or little impact on the other ECMs. Motor efficiency upgrades, lighting retrofit where power draw is measured periodically.
B. Retrofit Isolation Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.	Engineering calculations using shortterm or continuous measurements.	Application of controls to vary the load on a constant speed pump using a variable speed drive. Electricity use is measured by a kWh meter installed on the electrical supply to the pump motor. In the baseyear this meter is in place for a week to verify constant loading. The meter is in place throughout the post-retrofit period to track variations in energy use.

C. Whole Facility Savings are determined by measuring energy use at the whole facility level. Continuous observation of total energy use is made during the post-retrofit period.	Analysis of whole facility utility meter, sub-meter data, or fuel delivery information using regression modeling.	Multifaceted energy management program affecting many systems in a building. Energy use is measured by the fuel and electric utility meters for a 12 month baseyear period and throughout the post-retrofit period.
D. Calibrated Simulation Savings are determined through simulation of the energy use of components or the whole facility. Simulation routines must be demonstrated to adequately model actual energy performance measured in the facility. This option usually requires considerable skill in calibrated simulation.	Energy use simulation, calibrated with hourly or monthly utility billing data and/or end-use metering.	Multifaceted energy management programs affecting many systems in a building. Post-retrofit period energy use is measured by the fuel and electric utility meters. Baseyear energy use is determined by calibrated simulation.

3.2.1 Option A

3.2.1.1 Introduction

An Option A-based M&V method involves a retrofit or system-level M&V assessment. The approach is intended for retrofits where either performance factors (e.g., end-use capacity, demand, power) or operational factors (lighting operational hours, cooling ton-hours) can be spot or short-term measured during the baseline and post-installation periods. The factor not measured is stipulated based on assumptions, analysis of historical data, or manufacturer's data. Using a stipulated factor is appropriate only if supporting data demonstrates that its value is not subject to fluctuation over the term of the contract.

All end-use technologies can be verified using Option A; however, the accuracy of this option is generally inversely proportional to the complexity of the measure. In addition, within Option A, various methods and levels of accuracy in verifying performance/ operation are available. The level of accuracy depends on the validity of assumptions, quality of the equipment inventory, and whether spot or short-term measurements are made. The penalty associated with low accuracy is not achieving the estimated measure savings and the associated utility bill cost reductions.

Option A can be applied when identifying the potential to generate savings is the most critical M&V issue, including situations in which:

- The magnitude of savings is low for the entire project or a portion of the project to which Option A can be applied
- The risk of achieving savings is low or ESCO payments are not directly tied to actual savings

3.2.1.2 Approach

Option A is an approach designed for projects in which the potential to generate savings must be verified, but the actual savings can be determined from stipulated factors, short term data collection, and engineering calculations. Post-installation energy use is not measured throughout the term of the contract. Post-installation and perhaps baseline energy use is predicted using an engineering or statistical analysis of information that does not involve long-term measurements.

With Option A, savings are determined by measuring the capacity, efficiency, or operation of a system before and after a retrofit and by multiplying the difference by a stipulated factor. Stipulation is the easiest and least expensive method of determining savings. It can also be the least accurate and is typically the method with the greatest uncertainty of savings. This level of verification may suffice for certain types of projects in which a single factor represents a significant portion of the savings uncertainty. Option A is appropriate for projects in which both parties agree to a payment stream that is not subject to fluctuation due to changes in the operation or performance of the equipment. Payments could be subject to change based on periodic measurements, however.

3.2.1.3 M&V Considerations

Option A includes procedures for verifying the following:

- Baseline conditions have been properly defined
- The equipment and/or systems contracted to be installed were installed
- The installed equipment/systems meet contract specifications in terms of quantity, quality, and rating
- The installed equipment is operating and performing in accordance with contract specifications and is meeting all functional tests
- The installed equipment/ systems continue, during the term of the contract, to meet contract specifications in terms of quantity, quality, rating, operation, and functional performance

This level of verification is all that is contractually required for certain types of performance contracts. Baseline and post-installation conditions (e.g., equipment quantities and ratings such as lamp wattages, chiller kW/ton, motor kW, or boiler efficiency) represent a significant portion of the uncertainty associated with many projects.

All end-use technologies can be verified using Option A; however, the accuracy of this option is generally inversely proportional to the complexity of the measure. Thus, the savings from a simple lighting retrofit will typically be more accurately estimated with Option A than the savings from a chiller retrofit. If greater accuracy is required, Option B may be more appropriate.

Within Option A, various methods and levels of accuracy in verifying performance are available. The level of accuracy depends on the quality of assumptions made, and it can also depend on whether an inventory method is used for ensuring nameplate data and quantity of installed equipment or whether short-term measurements are used for verifying equipment ratings, capacity, operating hours and/or efficiency.

The potential to generate savings may be verified through observation, inspections, and/or spot/short-term metering conducted immediately before and/or immediately after installation. Annual (or some other regular interval) inspections may also be conducted to verify an ECM's or system's continued potential to generate savings.

Savings potential can be quantified using any number of methods, depending on contract accuracy requirements. Equipment performance can be obtained either directly (through actual measurement) or indirectly (through the use of manufacturer data). There may be sizable differences between published information and actual operating data.

Where discrepancies exist or are believed to exist, field-operating data should be obtained. This could include spot measurement for a constant load application. Short-term M&V can be used if the application is not proven to be a constant load. Baseline and post-installation equipment should be verified with the same level of detail. Either formally or informally, all equipment baselines should be verified for accuracy and for concurrence with stated operating conditions. Actual field audits are almost always required.

3.2.2 Option B

3.2.2.1 Introduction

Option B involves a retrofit or system-level M&V assessment. The approach is intended for retrofits with performance factors (e.g., end-use capacity, demand, power) and operational factors (lighting operational hours, cooling ton-hours) that can be measured at the component or system level. It is appropriate to use spot or short-term measurements to determine energy savings when variations in operations are not expected to change. When variations are expected, it is appropriate to measure factors continuously during the contract.

Option B is typically used when any or all of these conditions apply:

- For simple equipment replacement projects with energy savings that are less than **20%** of total facility energy use as recorded by the relevant utility meter or sub-meter
- When energy savings values per individual measure are desired
- When interactive effects are to be ignored or are stipulated using estimating methods that do not involve long-term measurements
- When the independent variables that affect energy use are not complex and excessively difficult or expensive to monitor
- When sub-meters already exist that record the energy use of subsystems under consideration

3.2.2.2 Approach

Option B verification procedures involve the same items as Option A but generally involve more end-use metering. Option B relies on the physical assessment of equipment change-outs to ensure the installation is to specification. The potential to generate savings is verified through observations, inspections, and spot, short-term, or continuous metering. The continuous metering of one or more variables may only occur after retrofit installation. Spot or short-term metering may be sufficient to characterize the baseline condition.

3.2.2.3 M&V Considerations

Option B is for projects in which (a) the potential to generate savings must be verified and (b) actual energy use during the contract term should be measured for comparison with the baseline model for calculating savings. Option B involves procedures for verifying the same items as Option A, plus the determination of energy savings during the contract term through short-term or continuous end-use metering.

Option B:

- Confirms that the proper equipment/systems were installed and that they have the potential to generate predicted savings
- Determines an energy (and cost) savings value using short-term or continuous measurement of performance and operating factors

All end-use technologies can be verified with Option B; however, the degree of difficulty and costs associated with verification increases as metering complexity increases. Energy-savings accuracy is defined by the owner or is negotiated with the ESCO. The task of measuring or determining energy savings using Option B can be more difficult and costly than that of Option A. Results are typically more precise, however, than the use of stipulations as defined for Option A.

Methods involve the use of pre- and post-installation measurement of one or more variables. If operation does not vary between pre and post conditions, monitoring pre-installation operation is not necessary. Spot or short-term measurements of factors are appropriate when variations in loads and operation are not expected. When variations are expected, it is appropriate to measure factors continuously. Performing continuous measurements (i.e., periodic measurements taken over the term of the contract) account for operating variations and will result in closer approximations of actual energy savings. Continuous measurements provide long-term persistence data on the energy use of the equipment or system. These data can be used to improve or optimize the operation of the equipment on a real-time basis, thereby improving the benefit of the retrofit. In situations such as constant-load retrofits there may be no inherent benefit of continuous over short-term measurements. Measurement of all affected pieces of equipment or systems may not be required if statistically valid sampling is used. For example, population samples may be measured to estimate operating hours for a selected group of lighting fixtures or the power draw of certain constant-load motors that have been determined to operate in a similar manner.

3.2.3 Option C

3.2.3.1 Introduction

Option C encompasses whole-facility or main-meter verification procedures that provide retrofit performance verification for those projects in which whole-facility baseline and post-installation data are available. Option C usually involves collecting historical whole-facility baseline energy use data and the continuous measuring of whole-facility energy use after ECM installation. Baseline and periodic inspections of the equipment are also warranted. Energy savings under Option C are estimated by developing statistically representative models of whole-facility energy consumption (e.g., kWh, kJ, or liters of fuel) as a function of readily quantified variables that affect energy use (e.g., outdoor temperature, unit production, occupancy rates).

In general, Option C can be used with complex equipment replacement and controls projects for which predicted savings are relatively large (i.e., greater than about **10%** to **20%** of the site's energy use), on a monthly basis. Option C regression methods are valuable for measuring interactions between energy systems or determining the impact of projects that cannot be measured directly, such as insulation, window films, or other building envelope measures. Specific difficulties associated with Option C methods include meeting the following requirements:

- Having available at least 12, and preferably 24, months of pre-installation data to calculate a baseline model
- Having available at least 9, and preferably 12, months of post-installation data to calculate first-year savings

- Collecting adequate non-energy-use data (e.g., weather, production, occupancy) in order to generate accurate baseline and post-installation models

3.2.3.2 Approach

With Option C, energy savings evaluations using facility-level metered data may be completed using techniques ranging from simple billing comparison to multivariate regression analysis. Utility bill comparison is the use of utility billing data (liters of fuel oil, kWh) and simple mathematical techniques to calculate annual energy savings. Utility bill comparison is a very simple and, typically, an unreliable method. It is applicable only to very simple ECMs in which energy use changes are a direct result of ECM installation and no other factors need be considered.

Option C regression modeling is a specific statistical technique appropriate for determining energy savings under a performance contract. Regression models can take into account the effects of weather and other independent variables on energy use; utility bill comparison techniques cannot. Utility bill regression analysis involves developing a model to estimate baseline energy use. Energy savings are estimated by comparing energy use predicted by the baseline model (forecasted into the post-installation period) to post-installation utility billing data. The analysis requires an empirical evaluation of the behavior of the facility as it relates to one or more independent variables. The variables may include weather, occupancy, and production rate.

3.2.3.3 M&V Considerations

The following points should be considered when conducting Option C analyses:

- All explanatory variables that affect energy consumption as well as possible interactive terms (i.e., combination of variables) must be specified, whether or not they are accounted for in the model. Critical variables can include weather, occupancy patterns, set points, and operating schedules. Independent variable data will need to correspond to the time periods of the billing meter reading dates and intervals.
- Weather (temperature) may not significantly affect energy use in Sri Lanka due to its consistency throughout the year, thus simplifying analysis. However, the effects of the monsoons (cloud cover) and the resulting solar radiation may affect air-conditioning loads. Weather should not be neglected entirely and factors other than temperature may have to be considered in some cases.
- Consistent weather patterns may cause other factors to exert a greater influence on energy use in Sri Lanka than they might in other locations. This will require greater diligence in collecting information relevant to energy use over the long term.
- The criteria used for identifying and eliminating outliers must be documented. Outliers are data beyond the expected range of values (or two to three standard deviations away from the average of the data). Outliers should be defined using common sense as well as common statistical practice.

3.2.4 Option D

3.2.4.1 Introduction

Option D involves the use of computer simulation software to predict facility energy use for baseline or post-retrofit energy use. Such simulation models must be “calibrated” so that it predicts an energy use and demand pattern that reasonably matches actual utility consumption and demand data from either the baseyear or a post-retrofit period.

Option D may be used to assess the performance of all ECMs in a facility, akin to Option C. However, unlike Option C, multiple runs of the simulation tool in Option D allow estimates of the savings attributable to each ECM within a multiple-ECM project.

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

3.2.4.2 Approach

The simulation model may involve elaborate models, spreadsheets, vendor estimating programs, and so on. Calibration is achieved by linking simulation inputs to actual operating conditions and comparing the simulation results with end-use or whole-facility data. The simulation may be of a whole facility or of just the affected ECM end-use.

3.2.4.3 M&V Considerations

The following points should be considered when completing simulations for M&V:

- Simulation analysis should be conducted by trained and experienced personnel who are familiar with the software used
- Input data should represent the best available information, including, if possible, the same or similar data and precautions described above for billing analysis
- The simulation should be calibrated by its ability to track with real utility billing data and/or sub-metering data with acceptable tolerances
- Simulation analyses should be well documented, with hard copy and electronic copies of input and output "decks" as well as the survey and metering /monitoring data used to define and calibrate the model

The purpose of any measurement & verification protocol is to guide the development of the M&V plan for a specific project. The plan contains the description of work to be performed, the results of measurements taken to date, the method by which energy and cost savings will be calculated, and all assumptions used within the calculations.

4.1 Selecting an M&V method

Since the primary purpose of M&V is to demonstrate performance and validate guarantees, the cost of M&V efforts should be relative to the project savings. Consequently, the objective of M&V should not necessarily be to derive a precise energy savings value but to ensure that the resulting energy savings are reasonably close to the savings predicted. The appropriate level of M&V rigor and accuracy is a level that protects the project investment. The selection of an M&V approach should include consideration of:

- Project cost
- Expected savings
- Uncertainty or risk of savings being achieved
- Risk allocation between the parties
- Whether the contract is based on guaranteed performance (fixed payments) or shared savings (variable payments)
- Number and complexity of dependent and independent variables that may need to be metered or accounted for in analyses
- Availability of existing data collecting systems (e.g., energy management systems), and
- Contract term

As noted, the level of certainty and thus effort required to verify a project's actual performance will vary from project to project. The project-specific M&V plan should be prepared with serious consideration of what M&V requirements, reviews, and costs will be specified. These are some factors that affect the decision of which M&V option and method to use for each ESCO project.

4.2 Risk Assessment

A key factor in the selection of an appropriate M&V plan is proper risk assessment. The major risks associated with an ESCO project can be classified as:

- Uncertainty risk
- Performance risk
- Usage risk, and
- Financial risk

The purpose of measurement & verification activities is to minimize risk to acceptable levels and allocate the remainder to the parties responsible for controlling them. All of the risk factors contribute to uncertainty in the savings estimates. If simple M&V methods with large amounts of uncertainty are used, then there is very little confidence in the savings estimates. This may mask savings shortfalls and presents a risk to the customer. More rigorous (and more costly)

M&V methods may reveal savings shortfalls that simpler methods do not. This is how M&V reduces risk— by identifying savings shortfalls. If these risks are understood, appropriate actions can be taken to mitigate them.

4.2.1 Uncertainty Risk

Uncertainty risk is simply the inability to quantify the savings exactly and consistently. Since savings are estimated by comparing a system with the way it operated before and the way it operates after a measure is installed, claimed savings are always estimates. Uncertainty in the estimated savings is introduced through:

- Measurement error
- Sampling error
- Random variations, and
- Simplifying assumptions

Even though a large number of parameters can be measured, there may still be errors associated with measuring equipment. Since not every piece of equipment can be measured, sampling techniques are often used, which can introduce additional uncertainty. Random variations occur in energy use or equipment that may be related to human behavior, weather conditions, or other random factors. Simplifying assumptions are sometimes used when it is too difficult to measure or estimate a parameter, introducing additional uncertainty.

All of these factors prevent obtaining a "true" estimate of the savings. In measurement and verification, the goal is to minimize these uncertainties to acceptable levels with the understanding that they can never be completely eliminated.

4.2.2 Performance Risk

Performance risk is related to actual equipment performance. Replacing old, inefficient equipment with new will usually provide savings. But new equipment will also become old and worn out with time, reducing its efficiency. A poor operations and maintenance (O&M) regimen can hasten degradation.

Occasionally, poor performance is due to faulty design or selecting the wrong piece of equipment for the job. These are factors that the ESCO controls, since, typically, it is the ESCO that is responsible for both proper design and performance of equipment. Because the ESCO usually assumes the responsibility of maintaining adequate performance, it usually assumes the savings risk.

4.2.3 Usage Risk

Usage risk is related to how much or how often a piece of equipment is used. Usage can be defined as:

- Operating hours (lighting, equipment)
- Occupancy or schedules
- Heating/cooling loads, and
- Production

The customer usually has control over the operating hours, the schedules, and whether the space is kept hotter or colder than originally intended. Although these factors significantly affect savings, the ESCO has little control over these and hence ESCOs are reluctant to assume the risks that arise from usage changes.

4.2.4 Financial Risk

Financial risk relates to factors such as interest rates and energy costs. Many of these are functions of market conditions. Neither the ESCO nor the customer has significant control over actual energy prices. For calculating savings, the value of saved energy may either be a constant, change at a fixed inflation rate, or float with market conditions. Depending on the market, either the ESCO or the client may be placed at a risk, if the value fluctuates.

Falling energy prices place the ESCO at risk of failing to meet the guaranteed cost savings. On the other hand, in the event of an energy price rise, there is a small risk to the client that energy-saving goals might not be met but the financial goals are. If the value of saved energy is fixed (either constant or escalated), the customer risks making payments in excess of actual energy cost savings.

To minimize uncertainty in long-term projects, the baseline and post-retrofit energy rates should be specified in the M&V plan. Allowing the energy rate upon which savings are based to fluctuate with market conditions means that the cost savings will likewise fluctuate, a situation that may affect project financing and customer dissatisfaction.

4.3 Stipulations

To stipulate a parameter is to hold its value constant regardless of what the actual value is during the contract term. A stipulation in an M&V plan is an agreement between the ESCO and the customer to accept a defined value or functional form of a specific factor to be used in determining the baseline and/or post-installation energy consumption, which will be used to estimate the savings. If related requirements are met (e.g., satisfactory commissioning results were submitted, annual verification of equipment performance is performed, and that maintenance is being done), the reported savings estimate is considered reliable.

Stipulated values must be based on reliable, traceable, and documented sources of information, such as:

- Standard lighting tables from recognized sources
- Manufacturer's specifications
- Building occupancy schedules
- Maintenance logs, and
- Performance curves published by recognized organizations

Sources of stipulated values must be documented in the M&V plan. Even when stipulated values are used in place of measurements, verifying equipment performance (technically, the *potential to perform*) is still required. *Note that direct stipulation of energy savings is not recommended.*

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

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

- The magnitude of the measure's cost savings
- Availability of reliable information

- The project's likelihood of success
- Uncertainty of the stipulated parameter and its contribution to overall project uncertainty,
- The cost of measurement, and
- Responsibilities of the ESCO and customer

Stipulations can be used to apportion risks and responsibilities to the appropriate parties. "Risk" in the M&V context refers to the uncertainty that expected savings will be realized. Both ESCOs and customers are reluctant to assume responsibility for factors they cannot control, and stipulations are often used to match control and responsibility. Risks in energy projects can be categorized as relating to either equipment performance or operational factors (usage).

Examples of commonly stipulated values include lighting-fixture operating hours and factory production levels. The customer controls these values, and by stipulating them, the customer is assuming the responsibility for any changes. Stipulating performance factors (e.g., lighting kW, motor efficiency) moves the responsibility for them from the ESCO to the customer. This is contrary to the intent of a guaranteed savings project and should be avoided.

4.4 Factors Affecting Savings Performance

Many factors affect the performance of equipment and achievement of savings. Depending upon the scope of the savings determination (its boundaries), the range of parameters of concern can be very focused (specific ECMs) or as wide as the whole facility.

In Chapter 3, Equation 1 (Energy Savings = Baseline – Post-retrofit ± Adjustments), parameters that are predictable and measurable can be used for routine adjustments. Such adjustments reduce the variability in reported savings, or provide a greater degree of certainty in reported savings.

Unpredictable parameters within the boundaries of a savings determination may require future non-routine baseline adjustments (e.g., load creep or addition of loads, power cuts, power interruptions and power quality such as variations in voltage or frequency). Unmeasured parameters give rise to savings fluctuations for which no adjustment can be computed, only guessed (e.g., raw material quality, air infiltration rate). Therefore, when developing an M&V plan, consideration should be given to the predictability of the relevant factor and how easy it is to measure it.

4.5 Evaluating Savings Uncertainty

The effort undertaken in determining savings should focus on managing the uncertainty created in the determination process. Projects with which the facility staff are familiar may require less effort than other, uncommon projects. The savings determination process itself introduces uncertainties through

- Instrumentation error
- Modeling error
- Sampling error, and
- Planned and unplanned changes

Methods of quantifying the first three errors are discussed in detail in IPMVP-2000. The last category of error above encompasses all the unquantifiable errors associated with stipulations, and the assumptions necessary for measurement and savings determination. It is feasible to quantify many but not all dimensions of the uncertainty in savings determination. Therefore, when planning an M&V process, consideration should be given to quantifying the quantifiable uncertainty factors and qualitatively assessing the unquantifiable. The objective is to consider all factors creating uncertainty, either qualitatively or quantitatively.

The accuracy of a savings estimate can be improved in two general ways. One is by reducing biases, by using better information or by using measured values in place of assumed or stipulated values. The second way is by reducing random errors, either by increasing the sample sizes, using a more efficient sample design, or applying better measurement techniques. In most cases, improving accuracy by any of these means increases M&V cost. Such extra cost should be justified by the value of the improved information.

Quantified uncertainty should be expressed in a statistically meaningful way, one that specifies both accuracy and confidence levels. For example, "The quantifiable error is found, with **90%** confidence, to be +/-**20%**." A statistical precision statement without a confidence level is meaningless since accuracy can sound very good if the confidence level is low. The appropriate level of accuracy for any savings determination is established by the concerned parties and will be influenced by the savings uncertainty and the M&V costs. Some issues in establishing a level of uncertainty are addressed in IPMVP 2000, but no recommendations are made.

If the energy consumption of the metered equipment or systems varies by more than **10%** from month to month, additional measurements must be taken at sufficient detail and over a long enough period of time to identify and document the source of the variances. Any major energy consumption variances due to seasonal production increases must also be tracked and recorded.

4.6 Minimum Energy Standards

When a certain level of efficiency is required either by law or the owner's standard practice, savings may be based on the difference between the post-retrofit energy use and the minimum standard. In these situations, baseyear energy use may be set equal to or less than the applicable minimum energy standards.

4.7 Minimum Operating Conditions

An energy-efficiency program should not compromise the operations of the facility to which it is applied without the agreement of the tenants, facility users, or process managers. Therefore the M&V plan should record the agreed conditions that will be maintained. This includes factors such as workplace lighting levels, air-condition setpoints and relative humidity, and production output.

4.8 Energy Prices

Energy cost savings may be calculated by applying the price of each energy or demand unit to the determined savings. The price of energy should be the energy provider's rate schedule or an appropriate simplification thereof. Appropriate simplifications use marginal prices which consider all aspects of billing affected by metered amounts, such as consumption charges, demand charges. The energy price used to determine the cost savings should be clearly specified in the contract for every year of the contract.

4.9 Baseline Adjustments (Routine)

Many factors affect the performance of equipment and achievement of savings. Depending upon the scope of the savings determination boundaries, the range of parameters of concern can be very focused or as wide as the whole facility. Examples of such parameters include lighting operating hours (focused) or monthly production (broad).

In Chapter 3, Equation 1 (Energy Savings = baseline – post-retrofit ± adjustments), parameters that are predictable and measurable can be used for routine baseline adjustments. Such adjustments reduce the variability in reported savings, or provide a greater degree of certainty in reported savings. Examples of variables that can be used for routine adjustments include facility or equipment operating hours, weather, hotel occupancy, or factory production.

4.10 Baseline Adjustments (Non-Routine)

Conditions which vary in a predictable fashion are normally included within the basic mathematical model used for routine adjustments. Where unexpected or one-time changes occur they may require non-routine or "baseline" adjustments.

These are examples of situations in which baseline adjustments are often needed:

- Changes in the end-use loads
- Changes in the amount or use of equipment
- Changes in set-point temperatures, and
- Changes in schedule or throughput

Baseline adjustments are not needed where:

- A key variable stipulated in the M&V plan changes in the post-retrofit period.. For example, if the number of hours of compressed air used were stipulated for an air compressor upgrade ECM, an increase in the running hours of the compressor will not affect the savings determined by the agreed simplified method, although actual savings will change.
- Changes occur to equipment beyond the boundary of the savings determination. For example, if the boundary includes only the lighting system, for a lighting retrofit, addition of personal computers to the space will not affect the savings determination.

Baseyear conditions should be well documented in the M&V plan so that proper adjustments can be made. It is also important to have a method of tracking and reporting changes to these conditions. This tracking of conditions may be performed by the facility owner, the agent determining savings, or a third party.The M&V plan should make clear who will track and report each condition recorded for the baseyear, and what, if any other aspects of facility operation will be monitored. Where the nature of future changes can be anticipated, methods for making the relevant non-routine baseline adjustments should be included in the M&V plan.

Non-routine baseline adjustments are determined from actual or assumed physical changes in equipment or operations. Sometimes it may be difficult to identify the impact of changes. If the facility's energy consumption record is used to identify such changes, the impact of the projects on the metered energy consumption must first be removed by Option B techniques.

4.11 Measurement & Verification Cost

The cost of determining savings depends on many factors, such as:

- M&V Option selected
- ECM number, complexity, and amount of interaction among them
- Number of energy flows across the boundary drawn around the ECM
- Level of detail and effort associated with establishing baseyear conditions
- Selected amount and complexity of the measurement equipment (design, installation, maintenance, calibration, reading, removal)
- Sample sizes used for metering representative equipment
- Amount of engineering required to make and support the stipulations used in Option A or the calibrated simulations of Option D
- Number and complexity of independent variables that are accounted for in mathematical models
- Duration of metering and reporting activities accuracy requirements
- Savings report requirements
- Process of reviewing or verifying reported savings, and
- The experience and professional qualifications of the people conducting the savings determination

Often these costs can be shared with other objectives, such as real-time control, operational feedback, or tenant sub-billing. It is difficult to generalize about costs for the different M&V options since each project will have its own unique set of constraints. However, it should be an objective of M&V planning to design the process to incur no more cost than needed to provide adequate certainty and verifiability in the reported savings, consistent with the overall project budget. However, it would not be expected that average annual savings determination costs exceed **10%** of the average annual savings being assessed. Table 4-1, below, highlights key cost governing factors unique to each Option.

Table 4-1: Unique Elements of M&V Costs

Option A	Number of measurement points Complexity of stipulation(s) Frequency of post-retrofit inspection(s)
Option B	Number of measurement points Frequency of measurements Complexity of stipulation(s)
Option C	Number of meters Number of independent variables needed to account for most of the variability in energy data
Option D	Number and complexity of systems simulated Number of field measurements needed to provide input data Skill of professional simulator in achieving calibration

4.12 Weather Data

Where monthly energy measurements are used, weather data should be recorded daily and matched to the actual energy metering period. For monthly or daily analysis, published weather data should be treated as the most accurate and reliable. However, weather data from such sources may not be available as quickly as site-monitored weather data.

When analyzing the response of energy use to weather in mathematical modeling, daily mean temperature data or degree-days may be used. However, temperature may not significantly affect energy use in Sri Lanka due to its consistency throughout the year, thus simplifying analysis. Alternatively, the effect of the monsoon on relative humidity and solar radiation may affect air conditioning loads. Weather should not be neglected entirely and factors other than temperature may have to be considered in some cases.

4.13 Balancing Uncertainty and Cost

There is no formal methodology to determine the most cost-effective M&V approach. It requires judgment, experience, and 'common-sense.' As a general rule, the annual savings determination costs should not exceed **10%** of the average annual savings while up-front costs should not exceed **10%** of the project capital cost. Technically complex projects may justify higher costs, at least for the first few installations. Simple projects should use simple and low-cost M&V approaches.

Option A commonly involves stipulation and fewer measurement points, which reduces costs relative to option B. However, more stipulation and less measurement results in greater uncertainty and project risk. Deciding which variables to measure and for what duration requires balancing M&V costs with project risk. Parameters that the ESCO is guaranteeing should be measured while parameters under customer control are often stipulated.

Option C can be used to reduce measurement costs provided that the anticipated energy reduction will be at least **10%** (and preferably **20%**) of the total energy use. If a number of measures have been installed at one site, Option C can often be less costly than multiple Option A or B approaches. The disadvantage is that Option C does not verify at the component level and it requires 6 to 12 months of data to reliably demonstrate that savings have been achieved.

Computer simulation methods are best applied to projects where simulation modeling is part of the design process itself (either major retrofit or new construction). This allows cost-sharing of an otherwise expensive M&V approach.

Common sense suggests that the M&V cost should not only be less than the expected savings but less than the uncertainty in the savings. If expected annual savings are Rs 1,000,000, and that doing no M&V results in an uncertainty of **50%**, then the uncertainty in the savings estimate is Rs 500,000. It therefore makes no sense to spend Rs 500,000 per year to quantify the savings while an expenditure of Rs 50,000 (**10%** of the uncertainty) seems quite reasonable. The quantity and the uncertainty of savings at stake places a limit on the M&V cost.

However, information derived from M&V activities may have additional value other than savings estimation. This includes better feedback to operations, enabling an enhancement of savings or other operational variables. The information may also be useful in assessing equipment sizing for planning plant expansions or replacement of equipment or for gaining experience with new technologies.

Discussions and definitions of site-specific M&V plans should include consideration of accuracy requirements for M&V activities and the importance of relating M&V costs and accuracy to the value of project savings. However, it should be recognized that not all uncertainties can be quantified. Therefore, both quantitative and qualitative uncertainty statements must be considered when considering M&V cost options for each project.

4.10 Reporting Requirements

The M&V plan serves as a central repository for the savings methodology, calculations, and supporting information such as measurement results and stipulated values. Periodic M&V reports provided to the customer serve as documentation of continued performance and savings. There is no requirement for the frequency of M&V reports, but a schedule should be set and documented in the M&V plan itself. Some customers like small monthly reports with a larger annual end-of-year report; others prefer annual reports only. The M&V report supports the invoice that the ESCO submits.

A project-specific M&V plan is required for each project site. The one exception to this rule is that a single project-specific M&V plan can be submitted for multiple project sites if, and only if, each project site has the *same* ESCO, measures, occupancy schedule, use, and energy consumption patterns as the others. It is the responsibility of the ESCO to document that the project sites meet these criteria. At a minimum, a project-specific M&V plan should include the following:

- A summary of the energy-efficiency measures being installed at the site, how those measures will save energy, and the key variables affecting the realization of energy savings.
- Key assumptions about significant variables or unknowns. Describe any stipulations that will be made and the source of data for the stipulations.
- The name of the firm responsible for conducting M&V activities, and who specifically will conduct metering, analysis, and reporting activities.
- The methods of calculating both energy and cost savings. Indicate the key equations or analysis tools (such as DOE-2 computer simulation software). Include a complete “path” indicating how collected survey and metering data are used in the calculation of energy and cost savings.
- The methods for determining baseline energy consumption and making baseline adjustments.
- A discussion of the monitoring activities, metering equipment, equipment source and accuracy, calibration procedures, metering schedule (includes duration and time of day and year), and data format.
- A description of any sampled measurements being used, why it is required, sample sizes, how sample sizes were selected, and how random sampling points will be selected.
- Accuracy requirements to be achieved for at least the key components, if not for the entire analysis. *Example:* “Accuracy requirements for all power monitoring devices are specified as being within ±**2%** of true reading.”
- A discussion of how quality assurance is to be maintained and confirmed.
- A discussion of the reports to be prepared over the course of the contract, the content of each report, and the dates that the reports will be submitted. Electronic format data

directly from a meter or a data logger should be submitted for any short- or long-term metering.

- A schedule for implementing the M&V activities. This schedule must list each M&V task, the party responsible for performing the task, and the date the task will be completed.
- A table showing the cost of conducting M&V activities. Include equipment costs (purchase or lease costs) and labor costs. For labor costs, include a table with lines describing each major task, the hourly rate of performing that task, the number of hours the task requires, and the total cost for each task.

Figure 4-1 is a checklist to help with preparation of the project-specific M&V plan using methods defined in this document.[2]

[2] Adapted from the U.S. Federal Energy Management Program's "M&V Plan Review Checklist."

- Project site and project defined.
- Project-specific M&V plan is defined for each project, OR
- Project-specific M&V plan defined for multiple projects, if and only if:
  - Projects have the same ESCO, and
  - Project sites have the same occupancy schedules, use, and energy consumption patterns.
- M&V method(s) (chapters) for each measure is defined.
- Who will conduct the M&V activities and prepare M&V analyses and documentation is defined.
- Details of how calculations will be made are defined. All equations are shown. Provided information shows how collected data and assumptions are used to calculate resulting savings that will be presented to Agency.
- Metering equipment is specified, including who will provide equipment, establish and ensure its accuracy and perform calibration procedures.
  - Generic types of metering equipment are indicated, OR
  - Specific meters with specifications are indicated.
- Schedule of metering, including duration and when it will occur is defined.
- How data from metering will be validated and reported, including formats, are defined.
- Electronic, formatted data, directly from a meter or data logger, will be provided.
- Key assumptions about significant variables or unknowns are defined.
- Any stipulations, as well as the source of data for the stipulations, are defined.
- How any baseline adjustments will be made is defined.
- Any sampling that will be used, why it is required, sample sizes, documentation on how sample sizes were selected, and information on how random sample points will be selected are defined.
- Level of accuracy that should be achieved is defined.
- How quality assurance will be maintained and repeatability confirmed is defined.
- How the quality of service will be verified is defined.
- How the power quality and other minimum equipment standards will be verified is defined.
- Reports are defined, including what they will contain and when they will be provided.
- Electronic formats and software programs to be used for reporting are defined.

Project Name and ID: ____

Date: _____________ Completed By: __________________________

Figure 4-1: Checklist for Project-Specific M&V Plans

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