A Best Practice Guide to Measurement and Verification of Energy Savings

A companion document to 'A Best Practice Guide to Energy Performance Contracts'

Produced by:
The Australasian Energy Performance Contracting Association for the Innovation Access Program of AusIndustry in the Australian Department of Industry Tourism and Resources

AEPCA

An Australian Government Initiative

AusIndustry

Disclaimer

The Australasian Energy Performance Contracting Association prepared this publication for the Innovation Access Program of AusIndustry. It was created by Energy Decisions Pty Ltd, with contributions from Robert Turner Consulting Pty Ltd and Barringer Leather Lawyers.

This guide is one of a continuously growing list of separate documents prepared by the AEPCA that should be read together. At the date of publication of this M&V Guide the list comprises:

- *Standard Detailed Facility Study Agreement*, available from your ESCO when you are procuring an EPC or, less often, by purchase from AEPCA
- *Standard Energy Performance Contract*, available as for the Detailed Facility Study Agreement and
- *Best Practice Guide to Energy Performance Contracts*, available to download free from the AEPCA web site

---

The information, opinions and advice presented in these documents and this guide are intended for information purposes only, and are not intended to be definitive or complete. You should not rely solely on the contents of any of them, but should consult your own professional advisers before taking any action in relation to the matters set out in the guide. AEPCA, its related and member organisations and all of the authors of the publications hereby exclude all liability of any kind (to the extent that such liability can be excluded) for the contents of the guide or for any consequences arising from its use or from any reliance placed upon it.

ISBN 0-646-44370-4

INNOVATION ACCESS PROGRAM (IAccP)

The Australian Government's Innovation Access Program - Industry provides grants for industry-led projects as part of its support for innovation, investment and international competitiveness of Australian businesses.

The program is offered through AusIndustry and adopts the take-up of technologies and best practice processes to enhance the competitiveness of Australian companies. This can include grants for international specialist visits to Australia, technology access workshops, and demonstration and awareness projects. Private sector companies, industry groups, universities, scientific agencies and training institutions are all eligible for funding.

AusIndustry delivers about 25 products worth nearly $2 billion to some 9000 customers every year around Australia.

THE AUSTRALASIAN ENERGY PERFORMANCE CONTRACTING ASSOCIATION INC. (AEPCA)

The AEPCA, formed in 1998, is the peak body representing the Energy Performance Contracting industry in Australia. Members include the major firms operating in the industry, specialist consultants and associated companies. The AEPCA's mission is to act as the peak body to support the commercial growth of the industry, its members and their market through customer and industry education, industry promotion, self-regulation and industry standards.

AEPCA has initiated, and will continue to develop, links with other key industry bodies that share its objectives for energy efficiency and greenhouse abatement, such as the Business Council for Sustainable Energy (BCSE).

For more details on AEPCA refer to the web site at http://www.aepca.asn.au

CONTENTS

ABBREVIATIONS

The following abbreviations are used throughout this guide and accompanying documents.

ABGR	Australian Building Greenhouse Rating
AEPCA	Australasian Energy Performance Contracting Association
AGO	Australian Greenhouse Office
ASHRAE	The American Society for Heating, Refrigeration and Air-conditioning Engineers
BPG-EPC	Best Practice Guide to Energy Performance Contracting
BPG-M&V	Best Practice Guide to Measurement and Verification
CMVP	Certified Measurement and Verification Professional
DFSA	Detailed Facility Study Agreement
ECM	Energy Conservation Measure
EE	Energy Efficiency
EOI	Expression of Interest
EPC	Energy Performance Contract or Contracting
ESCO	Energy Services Company
FAQ	Frequently Asked Questions
FEMP	Federal Energy Management Program (U.S.)
GHG	greenhouse gas
HVAC	Heating, Ventilation and Air Conditioning
IAccP	Innovation Access Program
IAQ	Indoor Air Quality
IPMVP	International Performance Measurement & Verification Protocol
IRR	Internal Rate of Return
M&T	Monitoring and Targeting
M&V	Measurement and Verification
MVP	Measurement and Verification Plan
NABERS	National Australian Built Environment Rating System
O&M	Operations and Maintenance
RFP	Request for Proposal
ROI	Return on Investment

THE GUIDE IN BRIEF

Note: throughout this Guide the term ‘energy’ should be taken to also include energy demand and water, where appropriate.

Why measure and verify?

Investment in energy efficiency offers the largest and most cost-effective opportunity for private and public sector organisations to limit the financial, health and environmental costs of burning fossil fuels. Such investment opportunities in Australia are estimated to be in the order of hundreds of millions of dollars to tens of millions of dollars per year, however actual investment is far less. The 2004 Commonwealth White Paper on Energy identifies a $9.4b net economic benefit to Australia from investing in energy efficiency by 2020 and the National Framework for Energy Efficiency identified a $1.8b net improvement to GDP from a 50% uptake of 4 year payback energy efficiency opportunities over 12 years.

When organisations – public or private - invest in energy efficiency, their executives naturally want to know how much they have saved and how long their savings will last. If the installation had been made to <u>generate</u> energy, then measurements would be trivial – install a meter on the generation equipment. Unlike energy generation, the determination of energy <u>savings</u> is a challenge, and requires both accurate measurement and repeatable methodology, known as a measurement and verification (M&V) protocol.

In Australia, as elsewhere, the long-term success of energy savings projects has been hampered by the inability of project partners to agree on how the energy savings can be measured and verified to <u>prove</u> that the projects have been successful. AEPCA identified a need for an Australian Guide to M&V of Energy Savings which would collect and present the best available knowledge from local and international sources.

This M&V Guide discusses procedures that, when implemented, allow buyers, sellers and financiers of energy projects to quantify the performance of an implemented Energy Conservation Measure (ECM) performance by measuring and verifying the energy savings achieved by the ECM. Using the internationally accepted M&V protocol and guidelines discussed in this document allows various risk issues associated with achieving these savings to be identified and allocated to the buyer or seller of the project, which facilitates the financing by allowing better risk management.

A review of several hundred million dollars of efficiency investments in buildings in the United States demonstrated that projects with strong M&V result in a substantially higher level of savings than projects that have little or no M&V. The data indicates that building retrofits that follow strong M&V practices – like those contained in this Guide – typically experience energy savings that are on average about 20 to 30 percent higher than buildings retrofitted with little or no M&V. The added cost of a strong M&V program is typically about five percent of the retrofit cost, but is typically paid back in months, both from substantially higher savings and by lowered operations and maintenance (O&M) costs (Kats and Rosenfeld et al. 1996).

Facility/Energy Managers in Australia have been monitoring energy consumption in facilities for many years, however there are concerns about the accuracy of many of the reported outcomes. The use of the M&V protocol and practices described in this Guide will ensure that the reported outcomes are valid and verifiable.

There are compelling incentives on both public and private sector facility owners/managers to increase the rigour and transparency of how they report on-going energy performance of their facilities. Reasons include:

- Increasing awareness of the economic, environmental, health and social costs of greenhouse gas emissions (GHG)
- Increasing compliance requirements from Governments to reduce GHG emissions
- Increasing pressures on budgets for real cost reductions in energy usage
- Increasing demands for performance measurement and accountability against targets and promised savings outcomes

What is M&V?

Measurement and verification (M&V) methods are used to measure and verify, in a defined, disciplined, rigorous and transparent way, the energy savings resulting from implementation of ECMs, which have been planned and designed to improve the energy performance of a specific facility or group of specific facilities. This is done without regard to the energy performance of any facility other than the one at which a change in energy infrastructure is implemented. This is in contrast to other methods – such as ABGR, NatHERS and the like – that monitor, target, benchmark, rate, or simply analyse and report energy performance by reference to groups of other similar facilities.

M&V provides certainty that reported results are real and verifiable. The real-life example in Chapter 11 dramatically shows the benefit of the M&V methodologies described in this Guide, when a **reported reduction of 25%** in annual energy consumption, relative to the previous year was shown to actually be an **increase of 11%** when the reported reduction was corrected for the inherent influence of weather on the measured consumptions for the two years.

Who Should Use M&V

M&V should be used by anyone wishing to prove the achievement of savings in utility resources, such as energy and water, delivered through any type of savings project or program. This includes:

- Building owners and managers, facility managers, plant and process engineers, financial controllers and procurement officers
- Energy Service Companies (ESCO) and other energy services professionals, such as energy auditors and energy management consultants, who provide advice or deliver energy savings through an energy performance (EPC), or other contracting arrangements
- Persons involved in developing, managing and/or reporting on energy savings policies and programs for a portfolio of facilities
- Anyone who is involved in the quantification and verification of reductions in Greenhouse Gas Emissions, the performance of renewable energy projects, and the effectiveness of demand-side management or demand response programs.

This Guide will be useful to all the above; it will also be helpful to persons involved in managing, planning and implementing M&V programs, including third-party M&V professionals and auditors, for any type of project or program that delivers energy savings.

For EPC projects, the M&V process is a formal and an integral part of the contractual arrangements. However, the same M&V methodologies and processes can be used by any other type of energy savings project or program. For these, the M&V may be less formal and less binding but it should still be based on the conceptual framework and methodologies described in this Guide.

Best Practice Guide to M&V

This Guide is intended to reduce major barriers to the energy efficiency industries by helping to:

- Increase the reliability and level of savings
- Reduce transaction costs by providing agreed M&V methodologies for the national industry
- Reduce financing costs and risks by providing standardisation of M&V for specific projects

This Guide provides an overview of current best practices for measuring and verifying savings outcomes of energy efficiency projects in Australia. It is the next in a series of documents produced by AEPCA to encourage and facilitate additional energy savings projects. It is a companion document to the BPG-EPC and provides additional conceptual and operational details about the use of M&V for EPC projects. **There are no other known resources on M&V within Australia. This guide is "recommended" reading for all parties involved in all types of energy savings or reporting projects.**

The Guide presents the basic conceptual framework, methodologies and processes of M&V and can be used by anyone interested in understanding or learning about M&V. It provides additional details and references to the M&V literature for those interested in participating in, or contributing to, an M&V program. M&V professionals require additional specialist knowledge, skills and experience beyond the scope of this Guide.

The information presented in this Guide is based primarily on (Refer to Appendix 1):

- The March 2002 edition of Volume 1 of the International Performance Measurement & Verification Protocol (IPMVP), entitled "Concepts and Options for Determining Energy and Water Savings"
- ASHRAE Guideline 14-2002
- U.S. Federal Energy Management Program (FEMP) M&V Guidelines Version 2.2

This Guide formalises basic M&V language, terms and techniques, and offers guidance on available methods from which you can choose the most appropriate level and formality of M&V for your specific project.

The essentials for adherence to this Guide are:

- There must be an agreed M&V Plan that is followed.
- One of the four (4) defined M&V Options must be selected, specified and followed.
- The accuracy and confidence level of savings must be reported.
- All M&V matters must be documented for independent verification.

Summary of M&V Plans

Refer Chapter 3 for more detail.

The preparation of an M&V Plan is the single most important M&V activity in an energy savings project. It is central to proper savings determination, and is the basis of verification. A plan is essential to assure the transparency of processes and the quality and credibility of achieved outcomes.

The objectives and constraints of the project and ECMs have a major influence on the preparation of the M&V Plan, as does the nature of the facility's usage patterns. Consideration of the amount of variation in energy patterns and the estimated impact of the ECM will help to establish the amount of effort needed to determine savings. The plan may include a single M&V Option that addresses all the ECMs installed at a single facility or it may include several M&V Options to address multiple ECMs.

An M&V Plan should be prepared during the project feasibility and definition stage as soon as the estimated savings of ECMs are known sufficiently to define M&V requirements. The ECMs should not be finalised until it has been established that there is a feasible and practical way of measuring and verifying the expected savings outcomes.

An M&V Plan should include much of the following:

- description of ECMs and intended results
- identification of the "measurement boundary"
- documentation of the facility's baseyear conditions and energy data
- identification of any planned changes to conditions of the baseyear
- identification of the post-retrofit period
- the set of conditions to which all energy measurements will be adjusted
- specification of M&V Options
- specification of data analysis
- procedures, algorithms and assumptions
- details of metering and method of dealing with missing/erroneous data
- for Option A, details of any stipulated parameters
- for Option D, details of simulation software
- quality assurance procedures
- expected accuracy of measurements, data capture and analysis
- documentation and data available for another party to verify reported savings
- methods for making relevant Baseline Adjustments fo unforeseen changes
- budget and resource requirements

Summary of M&V Options

Refer Chapter 4 for more detail.

Options A and B are used if your ECM is about improving the efficiency of operation of end-use equipment, such as a lighting installation, chiller, pump or boiler, and the like.

Option A – Partially Measured Retrofit Isolation

This is used for a single ECM where usually its performance can be measured but it may be best to stipulate it's operation. The savings are verified by engineering calculations using short term or continuous post-retrofit measurements and stipulations.

> Example: you change the type of lamp light fitting in a lighting installation to more efficient types as your ECM, maintaining the same quality of lighting. You may be able to measure the energy used by the old and new lighting systems, and hence the savings, but you may need to stipulate the number of hours of use, if the lights are controlled manually.
>
> Savings kWh = (old energy use kW – new energy use kW) x stipulated hours of operation

Option B – Retrofit Isolation

This is used for a single ECM where both the performance and the operation of the ECM should be measured. The saving is verified by engineering calculations using only short-term or continuous measurements.

Example: in the example above, if you also included automatic lighting controls in the ECM there would be no point stipulating hours of operation as that would not allow measurement of the impact of the controls. So here you would measure total consumption before the ECM, and total consumption after the ECM, and compare.

Savings kWh = old energy use kWh – new energy use kWh

Option C – Whole Facility (Building)

This is used for a single ECM or multiple ECMs within a whole facility or building. Energy use is measured by utility meters for at least 12 months of the baseyear and continuously throughout the post-retrofit period. The actual measured consumption in the post-retrofit period is compared with an estimate of what the consumption would have been, in the post-retrofit period, without the ECM. The accuracy of this estimation is the key to this Option, using techniques from simple billing data comparison to multivariate regression analysis. The process involves using historical data (baseyear) to develop a model of the energy performance of the facility, then using the baseline model to estimate the "baseline energy" in the post-rerofit oeriod, that would have been measured if theECM had not been installed.

The post-retrofit savings are the difference between the estimated "baseline energy" in the post-retrofit and the actual energy measured in the post-retrofit period.

Example: a whole building is retrofitted with numerous ECMs including lighting and HVAC. As well as their individual contribution to savings the ECMs also interact (e.g. reducing lighting impacts on heating and cooling) so the overall effect is complex. Option C is used to provide weather-corrected reporting of comparative energy usage between two periods. Refer to Appendix 4 for more discussion on the use of statistical modeling to develop the M&V computations.

Option D – Calibrated Simulation

This is used for a single ECM or multiple ECMs within a whole building but where no baseyear data are available, either because no records exist or, more commonly, because it is a new building. Post-retrofit measurements are used to calibrate the simulation model, and baseyear energy use and demand are generated by the simulation model. This Option is not used widely as it it requires specialist simulation skills and software.

Example: a new energy efficient building has been operating for 12 months. A simulation model based on technical inputs has been developed and calibrated with the actual operational consumption. This model can be used to estimate the likely consumption if the various ECMs had not been included. The consumption difference is a measure of the impact of the ECMs

Cost and Uncertainty

Refer Chapter 7 for more details.

An objective of M&V planning is to design the process to incur no more cost than needed to provide adequate certainty and verifiability in the reported savings. The issue is: "how much certainty is enough, and what is a reasonable cost?"

The value of savings for a specific project places limits on the expenditure that can be justified for M&V. Conversely, the number, type and complexity of ECMs in the project increases the M&V effort and expenditure for a given level of savings certainty. Clearly a project with constant load and operating hours is easier to deal with (and hence cheaper) than one with variable load, variable operating hours, and with non-ECM factors, (such as weather, occupancy or production levels) that influence the energy usage over time.

Option A normally has the lowest cost although, for multiple ECMs, sometimes the cost of using measurement equipment required for Options A or B may make Option C less costly. It may also be less costly to use Options C or D than to isolate and measure each ECM with Options A or B. Development and calibration of an Option D simulation model is time consuming, but it may have other uses such as in designing the ECMs themselves.

It is difficult to generalise about costs for the different Options however typically the cost ranges from 1% to 10% of annual savings, depemding on the project and ECM objectives and constraints.

The acceptable level of uncertainty in a savings calculation is a function of the value of expected savings and the cost effectiveness of decreasing uncertainty through additional time, effort and cost.

The M&V process itself introduces uncertainties through:

- Measurement and Instrumentation Errors: The magnitude of instrumentation errors stated in manufacturer's specifications are typically small and not a major source of error. Errors can be introduced through improper use or if calibrations are not maintained.
- Modelling Errors: They are inherent in creating and using the Baseline models or other computational models, and can be introduced by factors such as omitting important terms from the model, assigning incorrect values for "known" factors, and extrapolating results outside their range of validity.
- Sampling Errors: These result from the fact that measurements were taken from a sample rather than the entire set of items under study.
- Planned and Unplanned Assumptions: These errors cover all the unquantifiable errors associated with stipulations, and other assumptions.

Much but not all of the savings uncertainty can be quantified.The remaining unquantifiable uncertainty has to be assessed qualitatively.There are practical statistical techniques for combining the components of uncertainty and deriving and overall savings uncertainty. Quantified uncertainty should be expressed in a statistically meaningful way, by declaring both accuracy and confidence level.

Finding the best balance between savings uncertainty and M&V cost is simply a question of risk management; there is no one 'right' balance.

Future developments in M&V

This Guide has been given priority by AEPCA because of the increasing demands of customers to become involved in M&V decisions and because of wider interest from the public and private sector in M&V for for all types of energy savings projects.

This may increase the demand for further education and training, and the development of M&V professionals.

An accreditation program for M&V professionals has been created by the IPMVP and the Association of Energy Engineers (USA) http://www.ipmvp.org/services.html#CMVP Accredited M&V professionals are referred to as Certified Measurement and Verification Professionals (CMVP).

At the time of writing this Guide there is no equivalent accreditation in Australia. However, it is expected that an M&V accreditation process will be developed at some future date. Pending the development of an Australian M&V accreditation process, AEPCA recognises the international CMVP qualification http://www.aepca.asn.au/.

As stated in the Preface of the March 2002 edition of Volume 1 of the IPMVP, "as a living document, every new version of IPMVP will incorporate changes and improvements reflecting new research, improved methodologies and improved M&V data". This Guide may be updated from time to time to reflect changes to the IPMVP and other M&V guidelines. The AEPCA website will be used http://www.aepca.asn.au/ to maintain information about changes and improvements to this Guide

PREFACE

About this guide

This Best Practice Guide to Measurement and Verification (BPG-M&V) was produced by the Australasian Energy Performance Contracting Association Inc. (AEPCA) with the support of the Innovation Access Program (IAccP)managed by the AusIndustry.

With support from relevant Commonwealth and State Governments, AEPCA developed a set of standard contract documents and a Best Practice Guide to Energy Performance Contracts (BPG-EPC), which are being used widely by parties to an Energy Performance Contracting (EPC) arrangement. These documents are available on the AEPCA web site at http://www.aepca.asn.au/.

This Best Practice Guide is the next in a series of AEPCA documents to encourage more energy efficiency projects in Australia. It can be used for EPC projects and any other type of energy savings project or program. Measurement and verification (M&V) processes are an important and integral part of any energy savings project as they are used to determine, in a disciplined and transparent way, the amount, accuracy and confidence level of achieved savings.

Although this Guide formalises basic M&V language and techniques it is not meant to prescribe M& V methods and processes for every type of ECM. Instead this document offers guidance on the available methods from which you can choose the most appropriate. It helps clarify the relationship of various M&V methods to the risks assumed by relevant parties, and therefore helps you manage the financial risks of the project arrangements.

Throughout this guide the term “energy” and “energy savings” include both “energy” and “water”, and the term “consumption” may also include “demand”. Although there are differences between energy efficiency measures and water efficiency measures, they share many common attributes and are often part of the same project.

EPC projects

For readers who are parties to, or contemplating entering into, an Energy Performance Contract (EPC), this Guide is a supporting commentary on, and should be read in conjunction with the AEPCA standard EPC documents referred to previously.These documents include the necessary M&V guidance and obligations to determine energy savings in an Energy Performance Contract.This BPG-M&V guide provides further conceptual and operational details to help you understand and manage the M&V parts of the EPC project.

In particular, this Guide will assist you in understanding

- the practicality and cost-effectiveness of your project-specific M&V Plan, including the M&V methods selected for your project
- the savings determination methodology, and the factors that affect the credibility and quality of the reported savings performance
- the division of responsibilities between you and the ESCO, proactively managing savings risks and resolving any issues.
- the level of adherence to your M&V Plan, and the credibility and quality of the reported savings performance.

Other savings projects

For readers who are interested in using M&V methodologies for other types of energy savings projects or programs, this Guide will introduce you to the concepts and fundamentals of M&V so you can make informed decisions about how to best use M&V methodologies to achieve your energy savings objectives.

In particular, this Guide will assist you in

- preparing a practical and cost-effective M&V Plan and how to select the most appropriate M&V methods for your project
- using your M&V Plan and knowledge to obtain financing for your project or program.
- understanding the savings calculation methodology, and the factors affecting the quality and credibility of the reported savings outcomes.
- In understanding and proactively managing risks to the reported savings performance, and in taking action to resolve any issues.
- evaluating the level of adherence to the M&V Plan, and the quality and credibility of the reported savings.
- deciding whether you require professional assistance from others in managing, planning, implementing, evaluating and reporting your energy performance and/or savings outcomes

CHAPTER 1: INTRODUCTION

"You can't manage what you can't measure (and verify)"

Purpose of this Guide

This Guide provides information for all parties involved in measuring and verifying the outcomes of energy and water savings projects:

- ESCOs and other energy efficiency contractors will use this guide when planning and implementing M&V for their projects
- Facility owners and managers should use this guide to satisfy themselves about the soundness of the M&V for their project and when reviewing the M&V results reported by ESCOs and other energy efficiency contractors
- Government agencies may use this guide to assist them in planning and reporting greenhouse reduction programs or water use reduction programs.

What is Measurement and Verification (M&V)?

What M&V is

M&V methods and processes are used to measure and verify, in a defined, disciplined and transparent way, the energy savings resulting from planned and defined changes to all or parts of the energy infrastructure of a specific facility or a group of specific facilities. The savings are measured and verified without regard to the energy performance of any facility other than the facility at which a Energy Conservation Measure (ECM) is implemented.

M&V is an active and on-going process. In a generic sense, M&V is what good facility staff should do continuously: measure energy performance, make changes to their energy infrastructure and/or operations and maintenance, and verify that the changes work as planned and continue to work over time. M&V requires additional discipline and transparency in measuring and verifying savings than normally is provided for facility/energy management. For EPC projects, the M&V process is formal and an integral part of the contractual arrangements.

M&V literature is dominated by the application of M&V to EPC projects. EPC projects have a contractual arrangement between two or more parties where payments are based on achieving specified results; typically, guaranteed reductions in energy consumption and/or operating costs. The discipline, rigour and transparency of the M&V methods used to determine the energy savings are central to the confidence that the contracting parties (ESCO, customer and financier) have in the financial evaluation and risk management of the project, and in the credibility and quality of the reported energy savings.

A typical EPC project has a capital investment requirement ranging from hundreds of thousands to millions of dollars. Consequently, it is understandable that parties to an EPC arrangement place great importance on the credibility of the M&V processes and methods that are used. It is reported in the literature that M&V is the second most important issue, after "pricing", in negotiating and managing an EPC arrangement.

For other energy savings projects, the M&V may be just as important but it may be less formal and less binding. M&V for these other types of projects should be based on the same conceptual framework and methodologies described in this Guide. Examples of other types of energy savings projects are described in Chapter 10.

What M&V is not

Traditional energy monitoring, accounting, analysis, and reporting of consumptions and costs is **not** measurement and verification (M&V), as understood and defined in the international literature and in this Guide. They are functions that facility and energy managers should do as a normal part of their responsibilities to manage the energy performances of their facilities. M&V has a more focused purpose and requires additional discipline, rigour and transparency.

In the United Kingdom and Europe, monitoring and targeting (M&T) is a term that includes the traditional energy monitoring, accounting, analysis and reporting functions. However, it has additional functionality that corrects the measured energy for changes in factors that influence consumption over time, such as weather, areas, occupancy and production levels. M&T is very useful in identifying (targeting) ECMs based on comparative information between one period and another. Even though there are similarities, M&T does **not** have the same focused purpose, discipline, rigour and transparency required for M&V.

Energy benchmarking and rating methods – such as ABGR, NatHERS and the Green Star program - are used for measuring, ranking and rating the energy, greenhouse gas and other environmental performance of facilities in comparison to other "similar" facilities or to pre-established benchmarks. These methods normalise energy consumption data for differences in factors such as area, occupancy, space utilisation, number of consumption devices, and climatic regions, so that the outcomes are as comparable as possible. The central concept underlying benchmarking and rating is "energy intensity", which is expressed in measures such as "units of consumption per square meter of area per occupant". Benchmarking and rating methods are very useful in identifying (targeting) potential ECMs and in providing a comparative measure of energy performance. Benchmarking and rating methods have a different purpose and focus to M&V. M&V focuses on quantifying, with a stated accuracy and confidence level, the achieved energy savings of site-specific ECMs.

Why measure and verify?

When facility owners/managers invest in energy efficiency projects, they want to know how much they will save, have saved, and how long the savings will last. The determination of energy savings requires both accurate measurement and repeatable methodology, known as an M&V protocol.

The long-term success of energy and water management projects is often hampered by the inability of project partners to agree on an accurate and credible M&V Plan. This Guide discusses procedures that, when implemented, help energy services providers, customers and financiers of energy efficiency projects to agree on how they should determine and quantify savings.

A major purpose of the IPMVP (refer to Appendix 1) and this Guide is to increase investment in energy efficiency. As explained in the IPMVP 2001 (March 2002) Volume 1 Chapter 1, this is done in at least six ways:

<u>Increase energy savings</u>

Accurate determination of savings gives facility owners and managers valuable feedback on the operation of their facility, allowing them to adjust facility management to deliver higher levels, greater persistence and reduced variability of savings.

<u>Reduce cost of financing of projects</u>

In Australia, there is a patchwork of inconsistent measurement and verification practices for energy efficiency projects. This reduces reliability and performance of efficiency investments and increases project transactions costs.

By providing greater and more reliable savings and a common approach to determining savings, it is expected that widespread adoption of this Guide will make energy efficiency investments more reliable and profitable, and reduce the savings risks to all parties.

<u>Encourage better project engineering</u>

Since good M&V practices are intimately related to good design of retrofit projects, this Guide's direction on M&V practice should encourage improved design of energy management projects. Good M&V design, and ongoing monitoring of performance will help create projects that work effectively for owners and users of facilities. Good energy management methods help reduce maintenance problems in facilities allowing them to run efficiently.

<u>Help demonstrate and capture the value of reduced emissions from energy efficiency and renewable investments</u>

Emissions reduced by energy efficiency projects include CO_2, and NO Determining the level of reduction of pollutants requires the ability to estimate actual energy savings with confidence.

This Guide provides a framework for calculating energy reductions before and after the implementation of projects and therefore can help energy efficiency investments be recognised as an emission management strategy. This will help attract funding for energy efficiency projects through the sale of documented emission credits.

Increase public understanding of energy management as a public policy tool

By improving the credibility of energy management projects, M&V increases public acceptance of these activities. This encourages investors to consider investing in energy efficiency projects or the emission credits they create. By enhancing savings, good M&V practice also brings more attention to the public benefits provided by good energy management, such as improved community health, reduced environmental degradation, and increased employment.

Help national and industry organisations promote and achieve resource efficiency and environmental objectives

This Guide can be adopted by national, state and local government agencies and by industry and trade organisations to help create investment in energy efficiency and achieve environmental and health benefits

Importance of M&V in financing energy efficiency

The key to unlocking the enormous potential for energy and water efficiency is securing financing. Good measurement practices and verifiability help secure funding for projects, as it increases the confidence that energy efficiency investments will result in savings streams sufficient to make debt repayments. M&V practices allow project performance risks to be understood, managed, and allocated among the parties.

Energy and water efficiency projects meet a range of objectives, including upgrading equipment, improving performance, helping to achieve environmental compliance, or simply saving energy and money. All projects have one thing in common, an initial investment. The type of investment may be an internal allocation of funds (in-house project) or it maybe a complex contractual arrangement with an ESCO or third-party financier.

All types of investments have a common goal – making money or a “return” on investment. This return is measured by various financial yardsticks such as simple payback, return on investment (ROI) or internal rate of return (IRR). The expected rate of return is affected by the risk associated with the investment. Typically, the higher the project risk, the greater the return demanded.

Risk takes a variety of forms in energy efficiency projects and most can be measured and/or evaluated. The accuracy and confidence level of the savings measurement is important for financial risk management. M&V Protocols and Guidelines provide guidance on how to reduce and manage uncertainties in the measured savings.

Why improve the accuracy of M&V?

Facility/Energy Managers have been monitoring energy consumption in facilities for many years. Energy consumption is measured at the boundaries of facilities by utility meters and the data (including utility costs) provided periodically in the utility bills. In some cases, sub-metering is installed to provide additional details of energy consumption for various parts of the facilities. The level of commitment and effort devoted to collecting, analysing and interpreting the available energy and cost data depends on the specific needs of the organisation, the facility operation and those responsible for energy management.

There are compelling incentives and demands on both public and private sector facility owners/managers to increase the discipline, rigour, and transparency on how they manage and report on-going energy performance of their facilities. Reasons include:

- increasing awareness of the economic, environmental, health and social costs of GHG emissions.
- increasing compliance requirements from Governments to reduce GHG emissions,
- increasing pressures on budgets for cost reduction
- increasing demands for performance measurement and accountability against targets

How are savings determined?

The basic M&V conceptual framework and methodology for determining energy savings is relatively simple.

The term “savings determination” is used widely to refer to the total process of using M&V methodologies to determine energy savings.

The folowing example describes a typical saving determination situation.

Example of a typical savings determination situation.

As a part of establishing an energy savings project, the contractor identifies and defines the ECMs that will be installed, together with the expected (guaranteed) savings that will be achieved after the installation and commissioning of these ECMs (the post-retrofit period). The energy savings are calculated as the difference between the consumption that would have been measured during the post-retrofit period, if the ECMs had not been installed, and the actual consumption measured during the post-retrofit period. The calculated energy savings are then reconciled against the expected (guaranteed) savings.

The conceptual challenge is that the energy savings are calculated as the difference between "real" actual measurements, taken during the post-retrofit period (after the ECMs are installed), and "estimated" values that would have been measured during the post-retrofit period if the ECMs had not been installed. The post-retrofit "estimated" values are called the "Baseline Energy" values and are often referred to, for convenience, as the "business as usual" values.

Even though the M&V literature refers to the "measurement (and verification)" of energy the reality is that the savings can't be measured by 'real" measuring equipment. Only the actual energy consumptions during the post-retrofit period (after the ECMs are installed)and the pre-retrofit period (before the installation of the ECMs) can be measured by "real" measuring equipment. In a typical energy savings project situation, the Baseline ("business as usual") Energy values are estimated by adjusting the pre-retrofit measurements to the post-retrofit conditions by using a transparent, pre-determined and pre-agreed M&V computational methodology.

The central challenge for the M&V methodology is how estimation of the Baseline Energy values is performed and how uncertainty (error) in the estimation can be minimised and quantified so all parties have confidence in the calculated energy savings which rely on the estimated Baseline Energy values.

The M&V concepts and methodologies used for savings determination are presented in Chapters 2 to 7.

Basis of Guide

The information in this Guide is based primarily on the March 2002 revised edition of Volume 1 of the International Performance Measurement & Verification Protocol (IPMVP), entitled "Concepts and Options for Determining Energy and Water Savings". The IPMVP documents are regarded internationally as the "bible" of M&V. The IPMVP is the culmination of many years of development of M&V concepts and methodologies through the cooperation of international experts and practitioners. It has been widely adopted internationally and "has become the de-facto protocol for measurement and verification of performance contracts" (Refer to Appendix 1).

This Guide draws heavily from the information in IPMVP Volume 1, adapting the information, adding additional contextual and explanatory material to assist understanding and use of the concepts, methodologies and processes presented in the IPMVP Volume 1. The use of this Guide will encourage a wider readership and adoption of the M&V concepts and methodologies described in the IPMVP.

This Guide also draws heavily from the information in ASHRAE Guideline 14-2002 and the U.S. Department of Energy's Federal Energy Management Program (FEMP) M&V Guidelines Version 2.2. The FEMP M&V Guidelines are based on the IPMVP but provide additional guidance to U.S. Federal Agencies on the application of the IPMVP to their specific energy savings projects. The ASHRAE Guideline 14-2002 provides detailed process and technical information on the "measurement of energy and demand savings".

Further details about the evolution, purpose and contents of the IPMVP, ASHRAE Guideline 14-2002, and the FEMP M&V Guidelines are presented in Appendix 1.

The BPG-EPC refers readers for M&V guidance to the IPMVP 1997 and the draft release of ASHRAE Guideline 14P, which were available at that the time of writing the BPG-EPC. Since then the March 2002 revision of IPMVP Volume 1 and the final version of ASHRAE Guideline 14-2002 have been released. A major purpose of this Guide is to make users of the BPG-EPC aware of the updated versions of IPMVP and ASHRAE 14, the key changes to guidelines, terms and definitions, and the additional guidance that is currently available.

Future developments in M&V

This Guide has been given priority by AEPCA because of the increasing demands of customers to become involved in M&V decisions and because of wider interest from the public and private sector in M&V for all types of energy savings projects.

This may increase the demand for further education and training, and the development of M&V professionals. An accreditation program for M&V professionals has been created by the IPMVP and the Association of Energy Engineers (USA) http://www.ipmvp.org/. Accredited M&V professionals are referred to as Certified Measurement and Verification Professionals (CMVP).

At the time of writing this Guide there is no equivalent accreditation in Australia. However, it is expected that an M&V accreditation process will be developed at some future date. Pending the development of an Australian M&V accreditation process, AEPCA recognises the international CMVP qualification.

As stated in the Preface of the March 2002 edition of Volume 1 of the IPMVP, "as a living document, every new version of IPMVP will incorporate changes and improvements reflecting new research, improved methodologies and improved M&V data". This Guide may be updated from time to time to reflect changes to the IPMVP and other M&V guidelines. The AEPCA website will be used http://www.aepca.asn.au/ to maintain information about changes and improvements to this Guide

Using this Guide

This Guide describes the M&V conceptual framework and the associated methods and processes used to determine the energy savings, with sufficient accuracy and confidence to satisfy the specific contractual and financial requirements of the parties to an energy savings project.

The conceptual framework and methodology for M&V are described in Chapter 2. The M&V processes and issues involved in determining the energy savings and the energy cost savings are presented in Chapters 3 to 8.

Chapters 2 to 8 can be applied to all types of energy savings projects and programs. The application of M&V to EPC projects is presented in Chapter 9. The application of M&V to other types of energy savings projects and programs are presented in Chapters 10 and 11.

This Guide:

- Provides parties to an energy efficiency project a common set of M&V terms to discuss key M&V issues, and establishes methods for measuring and verifying savings
- Contributes to reducing risk aversion to contracting arrangements for energy savings projects by providing confidence in the promised and achieved energy savings
- Defines broad techniques for determining savings from both a "whole facility" and individual technology level
- Applies to a variety of facilities including residential, commercial, institutional and industrial buildings, and industrial processes
- Outline procedures which (1) can be applied to similar projects throughout all geographic regions, and (2) are internationally accepted, impartial and reliable
- Provides procedures, with varying levels of accuracy and cost, for measuring and verifying (1) pre- and post retrofit conditions, and (2) long-term energy savings
- Creates a document with a set of methodologies and procedures that can evolve over time to meet new needs of parties interested in energy savings, as well as incorporating new developments in international M&V Protocols and Guidelines.

What you should remember while reading this Guide

- M&V is an important and integral part of all types of energy savings project.
- You should have confidence in this Guide as it is based primarily on the IPMVP which has been accepted internationally for many years
- The Guide does not prescribe what you should do but rather it helps you understand and be aware of what you could do and the choices you have to satisfy the M&V needs of your specific project.
- M&V discipline, rigour and transparency can reduce savings risk, improve project outcomes, and encourage investment in energy efficiency projects.
- M&V can help you secure financing for your project by reducing financial risks
- The M&V concepts and methodologies are quite simple and are based on common-sense and good quality management practices.
- Accept that savings can't be measured and can only be estimated – that is why you need disciplined methodologies and mathematics.

CHAPTER 2: M&V CONCEPTS AND METHODOLOGY

"If you don't know the game and the rules - don't play"

Background

Energy savings can't be measured directly by meters or instruments. Actual energy use can be measured directly before the retrofit (pre-retrofit measurements) and then after the retrofit (post-retrofit measurements). A number of factors, such as weather, occupancy and production levels, influence the measured variation of energy use over time, irrespective of whether an Energy Conservation Measure (ECM) has or has not been implemented. The purpose of M&V is to determine the changes between pre-retrofit and post-retrofit measurements, which can be declared as the energy savings caused by the ECM.

The central question in determining energy savings is how to separate changes in measurements attributable to the ECM from those changes that inevitably occur independent of the ECM.

The remaining questions are about how the savings determination should be conducted for various specific ECMs. These questions and related issues have been investigated and addressed in the International Measurement & Verification Protocol (IPMVP).The information in this Chapter is an adaptation of Chapter 3, "Basic Concepts and Methodology", of the IPMVP Volume 1.

The purpose of this Chapter is to provide an understanding of M&V language, terms, basic concepts, overall processes and methodologies. **When you have read this Chapter you will know why energy savings can't be measured and why adjustments are generally made to the pre-retrofit energy measurements before calculating the savings in the pre-retrofit period.** Details on how to apply the M&V concepts, processes and methodologies to specific energy savings projects are presented in subsequent Chapters.

In the remainder of the Guide the term "energy" is used for ease of reading, but the same M&V concepts, methodologies and processes apply to energy demand and water savings.

M&V conceptual framework

A scenario of a simplified energy savings project is presented to assist readers in visualising and understanding the M&V conceptual framework and overall methodology.

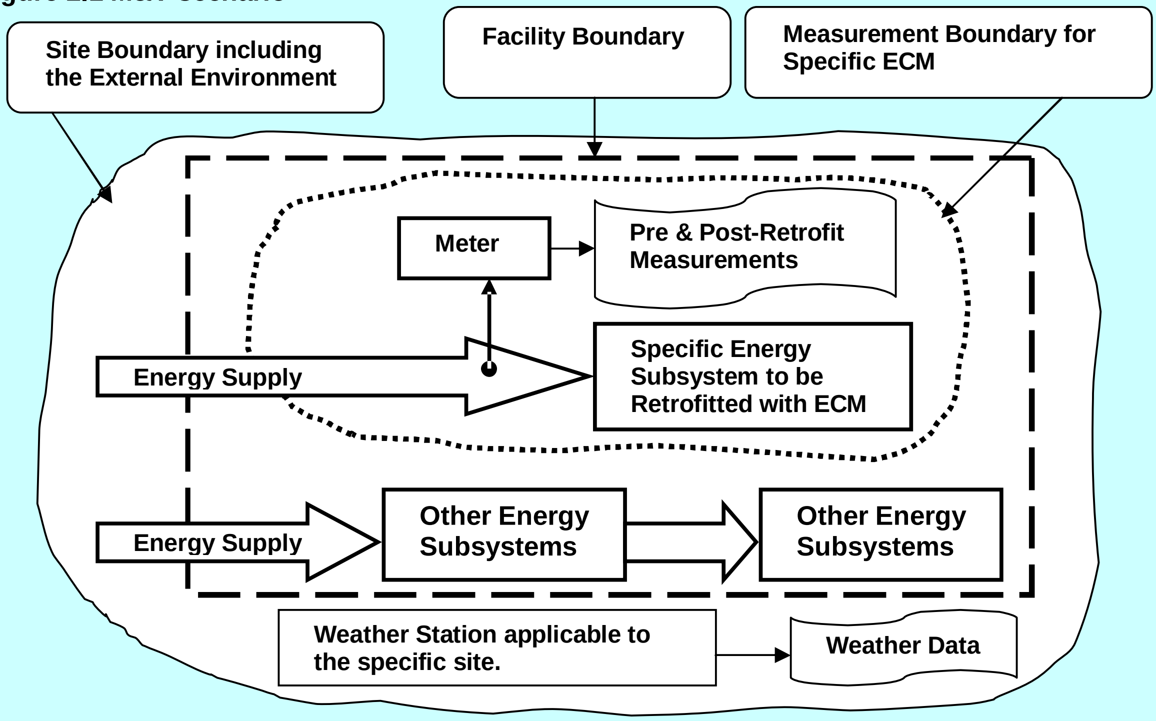
A specific facility at a specific site has three energy subsystems supplied by two external energy sources, as shown in Figure 2.1. The weather data for the site is available. Energy can be saved by retrofitting one of the energy subsystems with an ECM. The ECM and the estimated energy savings have been defined. Energy analysis of the ECM has shown that even though there are interactions between the three energy subsystems they can be ignored as they are not significant.

A financial evaluation of the project was conducted using the future cash flow stream from the estimated energy savings. The project was approved with the required capital and the installation of the ECM was completed.

The operation of the facility has been stable for about two years prior to the energy retrofit and was expected to remain stable over the next couple of years after the energy retrofit. The energy equipment has not been upgraded over the previous two years or so. Preventative and corrective maintenance has been, and will continue to be, conducted as required by the manufacturers.

A meter is available to measure the energy consumed by the specific energy subsystem that is to be retrofitted with the ECM. The "measurement boundary" for the ECM has been defined to ensure the measurements include only the consumption of the specific energy subsystem being retrofitted and does not include any consumption from energy interactions with energy subsystems outside the measurement boundary. Records of historical consumption are available for about two years before the ECM was installed and consumption was recorded for a period of one year after the installation of the ECM.

Figure 2.1 M&V scenario



Examples of the Application of the M&V Conceptual Framework

The M&V conceptual framework used for the above generic M&V scenario applies to all projects requiring energy savings determination: large and small, in-house, contracted projects with and without guarantees, energy performance contracting, demand-side management, portfolio energy reporting, and other project variants. It applies to all types of ECM technologies. The following are some practical examples.

Partial Lighting Retrofit: For a lighting retrofit project for a tenant occupying two floors of a multi-storey building, the facility boundary would be the two floors and the "measurement boundary" would be the tenant's lighting circuits (excluding consumption by other appliances on common power and light cabling). Data loggers would be used to measure consumption on the specific lighting circuits. Typically, data would be recorded for two weeks (covers weekday and weekend variations) before and after the retrofit. Energy interaction between lighting and air conditioning can be ignored. The site boundary and weather data are usually not relevant as weather has minimal influence on lighting, except for special cases such as daylight control.

Partial Motor Retrofit: The facility boundary for motor retrofits for a specific assembly line in a factory would be the part of the factory occupied by the assembly line and the "measurement boundary" would be typically defined for each individual motor. Data logging would be used for a representative period before and after the retrofit. If the factory was producing toilet paper, a short period (two weeks) of logging should be sufficient as production levels would be fairly constant over time. If the factory was producing ice cream, a longer representative period would be required to account for seasonal variations in production levels.

Partial Campus Retrofit: If the ECM is for one specific building in a campus, the site boundary is the campus boundary, the facility boundary is the specific building, and the measurement boundary would be the facility boundary, if a sub-meter is available for the whole building. Otherwise, the measurement boundary would be defined specifically for the ECM. Data logging would be used to measure the consumption if continuous consumption/demand data are not available from sub-meters.

Hospital Retrofit: A typical hospital energy savings project has a number of ECMs for various energy subsystems using electricity, gas and water. Because of energy interactions between the various subsystems, it is virtually impossible to define a measurement boundary for each ECM. All ECMs are included within the same measurement boundary, which is the same as the facility boundary. The continuous billing data from utility meters supplying the site are used as the measurement data. The weather data, recorded by the closest Bureau of Meteorology, is normally used for the site.

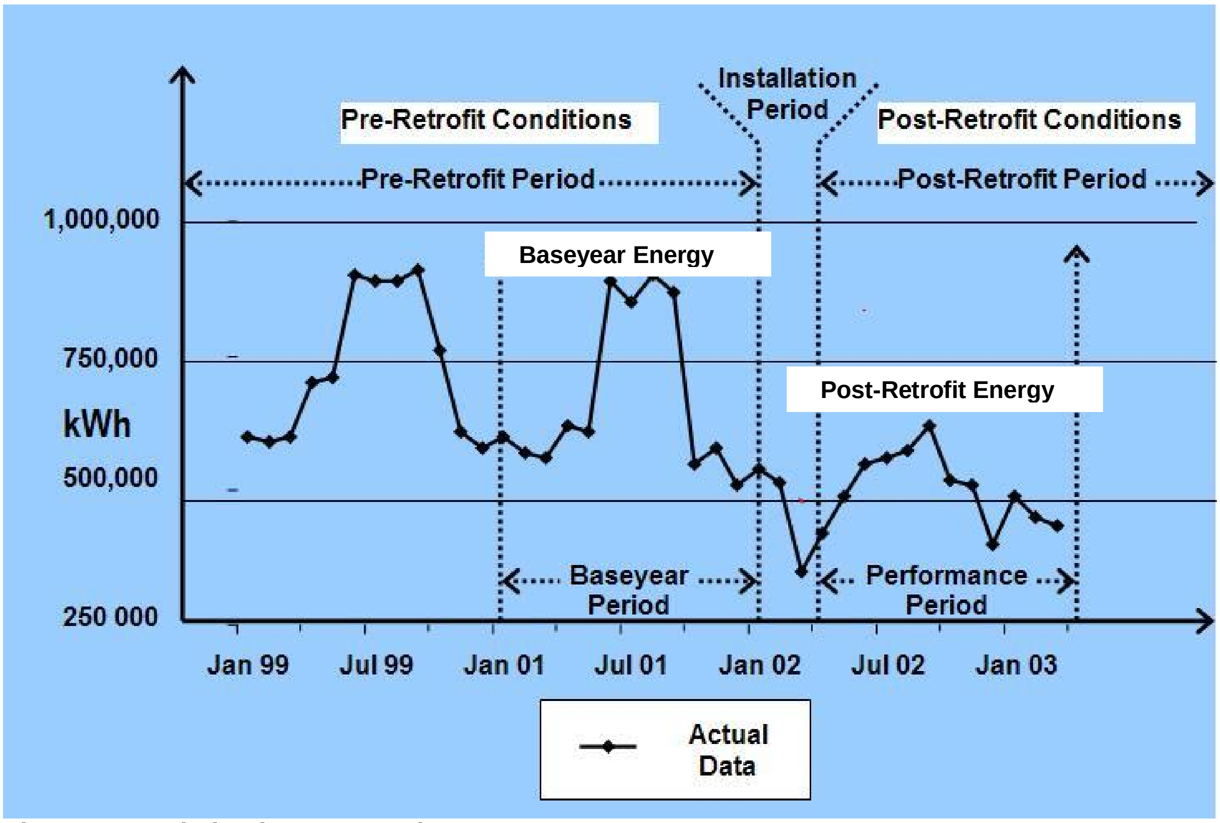


Figure 2.2 Variation in consumption

Figure 2.2 shows the variation in consumption for the pre-retrofit period, for the installation period, and for the post-retrofit performance period. The pre-retrofit measurements shows some seasonal variation in the consumption, which most likely can be attributable to weather variation. Weather data is available from the local Bureau of Meteorology weather station but no analysis had been done on the influence of weather on the consumption, measured before and after the retrofit.

From Figure 2.2, it appears that the ECM may have been effective in reducing consumption. However, it is not clear how much of the reduction is attributable to the ECM and how much is attributable to non-ECM factors, such as different weather conditions before and after the retrofit.

The energy savings attributable to the ECM can't be calculated simply as the difference between consumptions measured in the pre-retrofit and post-retrofit periods, as the difference inherently includes any changes in consumption caused by changes in weather or other non-ECM conditions between these two periods.

The M&V challenge is to identify, quantify and account for the energy changes caused by changes in non-ECM factors.

After accounting for energy changes caused by non-ECM factors, the energy savings – if any – attributable to the effectiveness of the ECM in reducing consumption can be determined.

M&V basic concept and methodology

The energy savings are determined by calculating the difference between the energy measured in the pre-retrofit and post-retrofit periods after accounting for differences in non-ECM factors between the two periods.

In general the savings equation is:

Savings = Baseyear Energy Use
– Post-Retrofit Energy Use
± Adjustments

The **"Baseyear Energy Use"** is the energy use measured for a defined period in the pre-retrofit period. Selection of the timing and length of the **"baseyear period"** is an important decision to be made during the savings determination process.

The baseyear period selection issues are discussed in Chapter 5. The baseyear period must end before the commencement of the ECM installation period so that the "Baseyear Energy Use" does not include any measurements taken during the installation period.

The **"Post-Retrofit Energy Use"** is the energy use measured for a defined period in the post-retrofit period. The defined post-retrofit period is commonly called **"Performance Period",** which can vary from about two weeks to 12 months, depending on the ECM type and technology.

The **"Adjustments"** term in the general equation corrects for the difference between the energy use, measured in the baseyear and performance periods, caused by any differences in non-ECM conditions influencing energy use between these two periods. Non-ECM conditions commonly affecting energy use are weather, occupancy, production levels; changes in equipment operations and maintenance conditions. Adjustments may be positive or negative.

Projected baseyear energy adjustments

Adjustments are commonly made to the baseyear energy use by projecting this energy use, measured under the prevailing conditions during the baseyear period, to the post-retrofit conditions. **This projected baseyear energy use is referred to as the "Baseline Energy".**

The "Baseline Energy" is the energy use that would have been measured during the post-retrofit period if the ECM had not been installed.

The "Baseline Energy" is commonly called the **"business as usual"** energy use of the post-retrofit period.

Baseline Energy
= Baseyear Energy $\pm$ ***Adjustments***

The Baseline Energy is often referred to as the **"Adjusted Baseyear Energy"**.

When the baseyear energy use is adjusted to the post-retrofit conditions, the savings are calculated by the following equation:

Savings
= Adjusted Baseyear Energy
– Post-Retrofit Energy
= Baseline Energy – Post-Retrofit Energy

where

- "Baseline Energy" is the actual Baseyear Energy adjusted to post-retrofit conditions
- "Post-Retrofit Energy" is the actual energy use measured in the Post-Retrofit Period

When the adjustment process is applied to the baseyear measurements, the savings are often described as **"avoided energy use in the post-retrofit period**"**.**

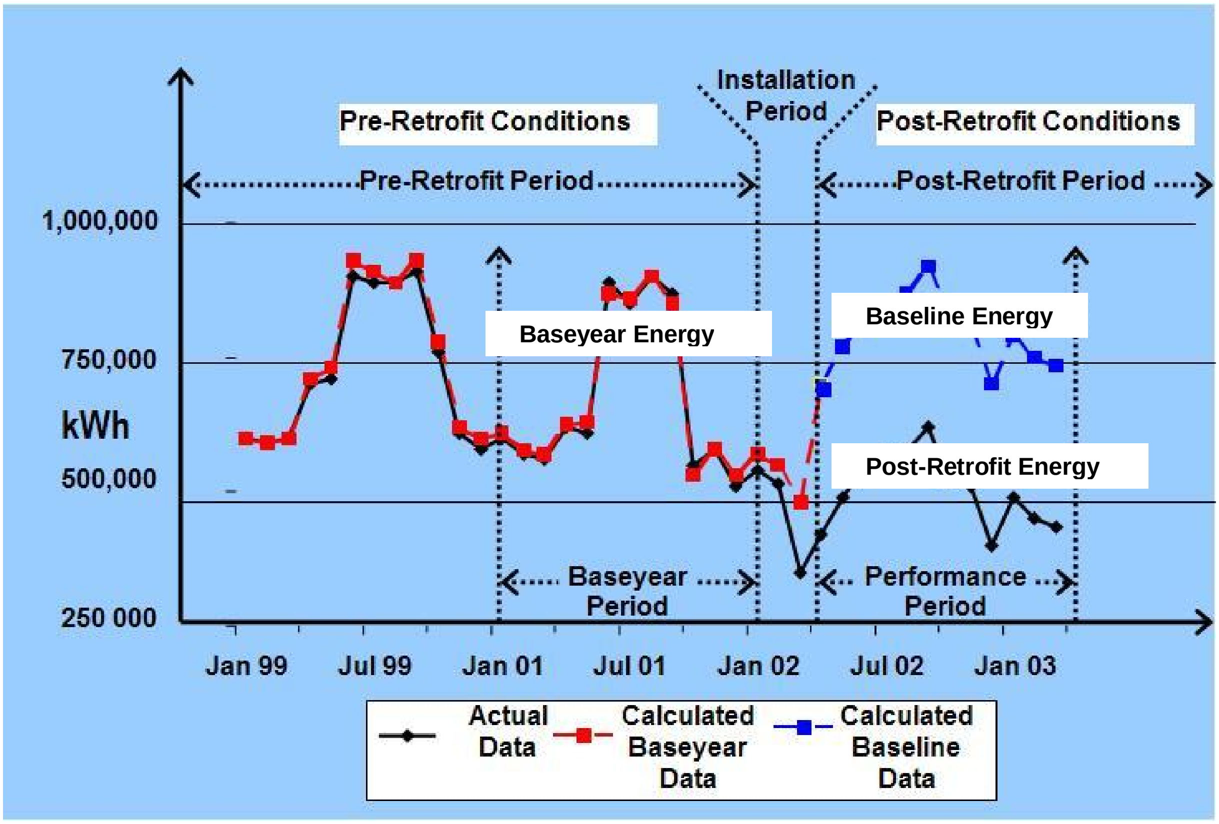


Figure 2.3 Calculated Baseline Energy data for the energy savings scenario

Figure 2.3 shows the addition of the calculated Baseline Energy data (shown in blue) to Figure 2.2 for the energy savings scenario described previously. The Baseline Energy data has been calculated by adjusting the Baseyear Energy data for the differences in the non-ECM conditions between the baseyear period and the post-retrofit (performance) period. The savings during the post-retrofit period is the difference between the calculated Baseline Energy use and the actual Post-Retrofit Energy use for the post-retrofit period. The area between the Baseline Energy plot line and the Post-Retrofit Energy plot line in the post-retrofit (performance) period is the "avoided energy use" for the post-retrofit period.

Figure 2.3 also shows a plot of "calculated baseyear energy" data (shown in red) which is generated as a part of the adjustments process used to calculate the Baseline Energy (shown in blue) from the Baseyear Energy. Because the "blue" Baseline Energy line is actually a calculated continuation of the "calculated baseyear energy" shown in "red", it is the best estimate of the energy use that would have been measured during the post-retrofit period if the ECM had not been installed: i.e. the "business as usual energy" in the post-retrofit period. The significance of the "calculated baseyear energy" data and its comparison to the "actual baseyear energy" data is discussed in Chapter 5.

<u>Other projected energy adjustments</u>

Adjustments may be made to the post-retrofit energy use by projecting back the post-retrofit energy use, measured under the prevailing conditions during the post-retrofit period, to the baseyear conditions. .

For this case, the projected post-retrofit energy is referred to as the "adjusted post-retrofit energy use" under baseyear conditions and the "savings" equation would be as follows:

Savings = Baseyear Energy
– Adjusted Post-Retrofit Energy

where

- "Baseyear Energy" is the actual energy measured in the pre-retrofit period
- "Adjusted Post-Retrofit Energy" is the Baseline Energy for the pre-retrofit period computed by adjusting the measured post-retrofit energy to pre-retrofit conditions

Adjustments may also be made to both the baseyear and post-retrofit measurements by projecting both measurements to an agreed fixed set of conditions, which could be a standard set of conditions or a set of conditions prevailing for any other period. In this case the savings are referred to as **"energy savings under defined conditions**".

It should be noted that it is important to state whether the adjustment is a projection forward to the post-retrofit period, back to the pre-retrofit period or to a common set of conditions.

<u>Projected energy adjustments in this Guide</u>

The most common type of adjustment is to calculate the Baseline Energy by adjusting the baseyear energy to the post-retrofit conditions.

Adjustments discussed in this Guide will be for the baseyear energy adjusted to the post-retrofit conditions, referred to as the "Baseline Energy" (post-retrofit period).

Examples of Adjustments

The following are two simplified examples of the need to use "adjustments".

<u>Lighting Retrofit:</u> The energy savings guaranteed for a Call Centre lighting retrofit project was based on a weekday two-shift operation. A separate sub-meter had been installed for lighting circuits. Six months after the retrofit completion, the Call Centre expanded its services and moved to a 7-day three-shift operation. The first annual energy savings calculation, ignoring the increased number operational hours in the post-retrofit period, showed no achieved energy savings. The expected savings were exceeded when the Baseline Energy was calculated by adjusting the 12-month baseyear consumption (for a weekday 2-shift operation) to the increased operational hours in the post-retrofit period. The savings calculation could have been done by adjusting the post-retrofit energy back to the same operational hours as for the baseyear operation.

<u>Additional Hospital Building:</u> The energy savings for a hospital retrofit project was based on using continuous monthly billing data from the utility meters measuring the whole-of-site consumptions. During the second 12-months of the post-retrofit period, a new building became operational. The additional consumption from this new building would have negated the achieved energy savings. The consumption measured by a sub-meter installed for the new building was used to adjust the post-retrofit energy measured by the utility meters (which now included the new building's consumption) back to only the buildings within the original measurement boundary for the project.

M&V processes and methods overview

Having established that “savings” can’t be measured – they have to be calculated (estimated) from pre-retrofit and post-retrofit measurements with appropriate adjustments for changes in non-ECM conditions – the remaining issues are about ensuring that M&V processes and methods produce “estimated” savings with sufficient accuracy and credibility to satisfy the requirements and expectations of all parties with interests in the reported project savings.

Most of the concerns about the use of M&V processes and methods, and acceptance of reported savings outcomes, are due to difficulties in understanding and believing the estimation parts of the savings determination methods. A primary purpose of this Guide is to address these concerns by establishing the propriety of the estimation methods and the overall M&V savings determination processes and methods.

As described in Appendix 1, the evolutionary development of the now well-established M&V processes and methods was driven by the need of all parties (ESCOs, financiers, government stakeholders and government agencies) involved in energy performance contracting projects in the USA to have a common set of national processes and methods which, if adhered to, could be relied upon to produce savings values with sufficient accuracy and credibility to satisfy all parties involved in all types of energy savings projects. The IPMVP, the FEMP M&V Guidelines and ASHRAE Guideline 14 are the key outcomes of this evolutionary development of the M&V processes, and methods.

The fundamental principles underlying these established M&V processes and methods are those of quality management and assurance of the reported savings outcome, which include concepts such as the following:

- Transparency
- Traceability
- Repeatability
- Verification
- Conformity (satisfying agreed requirements)
- Accuracy

As with all processes and methods developed to provide assurance of outcomes, the M&V protocols and guidelines describe a system with inputs and outputs, and with processes, procedures, methods and documentation.

The M&V protocols and guidelines provide assistance to undertake the following:

- Setting the M&V objectives and constraints consistent with the energy savings project objective and constraints
- Developing the M&V Plan and establishing an appropriate balance between M&V costs and savings risks
- Selecting the appropriate measurement and calculation methods for each ECM
- Implementing the planned M&V – collecting the actual measurement and non-ECM data for pre-retrofit and post-retrofit periods, calculating the Baseline Energy and the energy savings
- Taking preventive and corrective actions to address unforeseen M&V issues
- Verifying the M&V was implemented as planned
- Calculating and reporting the savings outcomes for the performance period as planned

Because of the diverse nature of the project situations, project objectives (including financial), project scopes, project ECMs, and availability of, or access to, measurement and non-ECM data the M&V protocols and guidelines have to be generic in nature, with guidance for specific types of ECMs and other situations. Project-specific M&V objectives and constraints, plans, processes, procedures and methods have to be established by the parties to each specific energy savings project.

As with any other system with a plan, processes, procedures and methods designed to calculate a result from the collection and processing of actual measurement and other associated data, there are errors in the calculated result and risks that the expected result may not be achieved. For M&V, the following errors and risks result in a savings uncertainty:

- Measurement errors and risks inherent in the use of meters and instruments
- Estimation errors and risks in calculating adjustments for the influence of non-ECM factors on energy consumption and for the impact of changes in non-ECM factors between the pre- and post-retrofit periods
- Sampling errors and risks from using sampling methods to estimate values for a population from a sample of the population
- Errors and risks from planned and unplanned assumptions for the conduct of the M&V

There are a range of costs that could be spent on implementing M&V for a specific project. In general, savings uncertainty can be reduced by spending more money on the M&V processes: similarly M&V costs can be reduced by accepting a higher level of savings uncertainty. For example:

- Measurement and instrumentation errors can be reduced by using more expensive equipment with increased precision
- Sampling errors can be reduced by spending additional money to increase the sample size
- Errors and risks can be reduced by spending additional money to measure a quantity rather than make an assumption about the quantity from manufacturer's published data

The decision on balancing costs and savings uncertainty have to be made for each specific project and should be made during the preparation of the M&V Plan for the specific project. **A primary objective of the M&V planning is to find the balance between costs and savings uncertainty within the project objectives and constraints**. **M&V should be planned and designed so that no more cost is incurred than is necessary to provide adequate savings uncertainty to satisfy the project requirements and constraints.**

Preparation and documentation of an M&V Plan is essential to assure the transparency of processes and the quality and credibility of achieved outcomes. Advance planning ensures that all data and computational processes needed for proper savings determination will be available after implementation of the energy savings program, within an acceptable budget.

M&V basic approach

The following are the basic process steps in planning, designing, implementing M&V for a specific project after the ECMs have been identified and the expected savings have been estimated.

Before ECM implementation

1. Prepare an M&V Plan (refer to Chapters 3 and 7) and select the M&V method (refer to Chapter 4) for each ECM based on the objectives and constraints for project and ECMs.
2. Gather relevant energy, operating and other non-ECM data from the baseyear, record it in an accessible way and incorporate it in the M&V Plan (refer to Chapter 6).
3. Determine the baseyear energy and non-energy data and the computational methods that will be used to calculate the Baseline Energy to post-retrofit conditions (Refer to Chapters 4 and 5).
4. Design, install and test any special measurement equipment needed under the M&V Plan (Refer to Chapter 6).

After ECM implementation

5. Verify that the M&V has been implemented. as specified in the M&V Plan, including any changes required during the implementation (Refer to Chapter 3).
6. Gather energy, operating and other non-ECM from the post-retrofit period, consistent with that of the baseyear and as defined in the M&V Plan.
7. Calulate and report achieved energy savings (refer to Chapters 4 and 5) and cost savings (refer to Chapter 8) and verify compliance with the M&V Plan.

What you should remember about M&V fundamentals

- Savings can't be measured. They are estimated from the pre- and post-retrofit energy measurements.
- The measurement boundary for an ECM or a group of ECMs has to be defined.
- Understanding the differences between pre-retrofit, baseyear, installation, post-retrofit and performance periods.
- The Baseline Energy in the post-retrofit period is the Baseyear Energy adjusted to the post-retrofit conditions.
- The "savings" are the difference between the estimated Baseline Energy and the actual Post-Retrofit Energy, both in the post-retrofit period.
- M&V protocols and guidelines have been developed to provide a consistent and verifiable approach for determining savings for all types of energy savings projects.
- There are inherent errors and risks that contribute to savings uncertainty. A balance has to be found between the M&V cost and the savings uncertainty, consistent with the project objectives and constraints.
- The fundamental importance of preparing, documenting and following an M&V Plan
- The basic approach to planning, designing, and implementing project-specific M&V and to reporting and verifying the savings.

CHAPTER 3: M&V PLAN

“If you don’t have a game plan - don’t expect to win”

Background

Preparation of an M&V Plan is the single most important M&V activity. The M&V Plan is central to proper savings determination and is the basis of verification. A plan is essential to assure the transparency of processes and the quality and credibility of achieved outcomes. Advance planning ensures that all the needed data and computational processes will be available for the savings determination within an acceptable budget.

Adherence to this Guide requires the preparation of a site-specific M&V plan for each ECM iin the energy savings project. In some circumstances a common M&V Plan can be used for a multi-site energy savings project. The M&V Plan must be agreed to by all parties involved in the project. The level of adherence to the M&V plan should be verified and documented in M&V project reports and in the performance period savings reports.

Data for the baseyear and details of the ECMs should be recorded for future reference, should conditions change or savings not be achieved. The M&V procedures and computational processes should be defined and all assumptions explicitly documented. Documentation should be prepared so that it is accessable for verification (including interested parties not involved in the M&V plan development) since several years may pass before the information may be needed for verification or resolving unforeseen issues.

The objectives and constraints of the project and ECMs have a major influence on the preparation of the M&V Plan, as does the facility’s usage patterns. The amount of variation in energy use patterns and the estimated impact of the ECMs will help to establish the amount of effort needed to determine savings. Generally, variable load or variable operating hours require more rigorous measurement and computation processes. These and other issues will affect the amount of effort required in collecting the data and in performing the computations.

The information in this Chapter is adapted from the IPMVP 2001 (March 2002) Volume 1 Section 3.3 and the FEMP M&V Guidelines Version 2.2.

The selection of the most appropriate M&V method and associated computational processes is discussed in Chapter 4 and 5, the measurement issues in Chapter 6 and cost-benefit considerations in Chapter 7. The conversion of the energy use savings to energy dollar savings is discussed in Chapter 8.

M&V Plan

The M&V plan is a document that defines project-specific M&V procedures and methods for determining the energy savings.

The plan may include a single M&V method for all ECMs installed at a single facility or it may include several M&V methods to address the individual M&V requirements of multiple ECMs.

The general steps, which can be iterative, for defining a project-specific M&V plan include:

- Specify the M&V objectives and constraints consistent with the energy savings project objectives and constraints.
- Specify the characteristics of the facility and the ECM or system to be installed.
- Specify by ECM the measurement boundary and the M&V methods and techniques to be used.
- Specify data analysis procedures, algorithms, data assumptions, data requirements, and the computational tools.
- Specify the measurement equipment, measurement points, measurement period (pre- and post- retrofit) and measurement analysis.
- Specify accuracy and quality assurance procedures, and identify savings risk.
- Specify the annual M&V report format and how results will be documented.
- Define budget and resource requirements.

When should the M&V Plan be prepared?

The initial M&V Plan should be prepared as soon as possible during the project feasibility and definition stage. Preparation should commence as soon as the ECMs, their intended impact and estimated savings are known sufficiently to define M&V requirements.

ECM details should not be finalised until it is determined there is a feasible way of measuring and verifying the savings.

The objectives and constraints of the project and ECMs set the requirements to be satisfied by the M&V methods. If a feasible cost-effective M&V Plan cannot be created the initial requirements, changes to the requirements may have to be considered. The M&V budget may have to be increased to pay for more extensive M&V. The planning process should iteratively refine the M&V Plan until the M&V requirements and the project/ECM budget constraints are satisfied. **It would be unwise to proceed with an energy savings project that does not have a defined and agreed way of measuring and verifying the savings outcomes.**

This iterative refinement should continue during the "investment grade audit" (Detailed Facilities Study phase described in BPG-EPC) phase of the project when detailed information is collected and details of the savings potential of each ECM are fully investigated.

A final M&V Plan should be prepared and submitted when the scope and details of design and installation work are finalised.

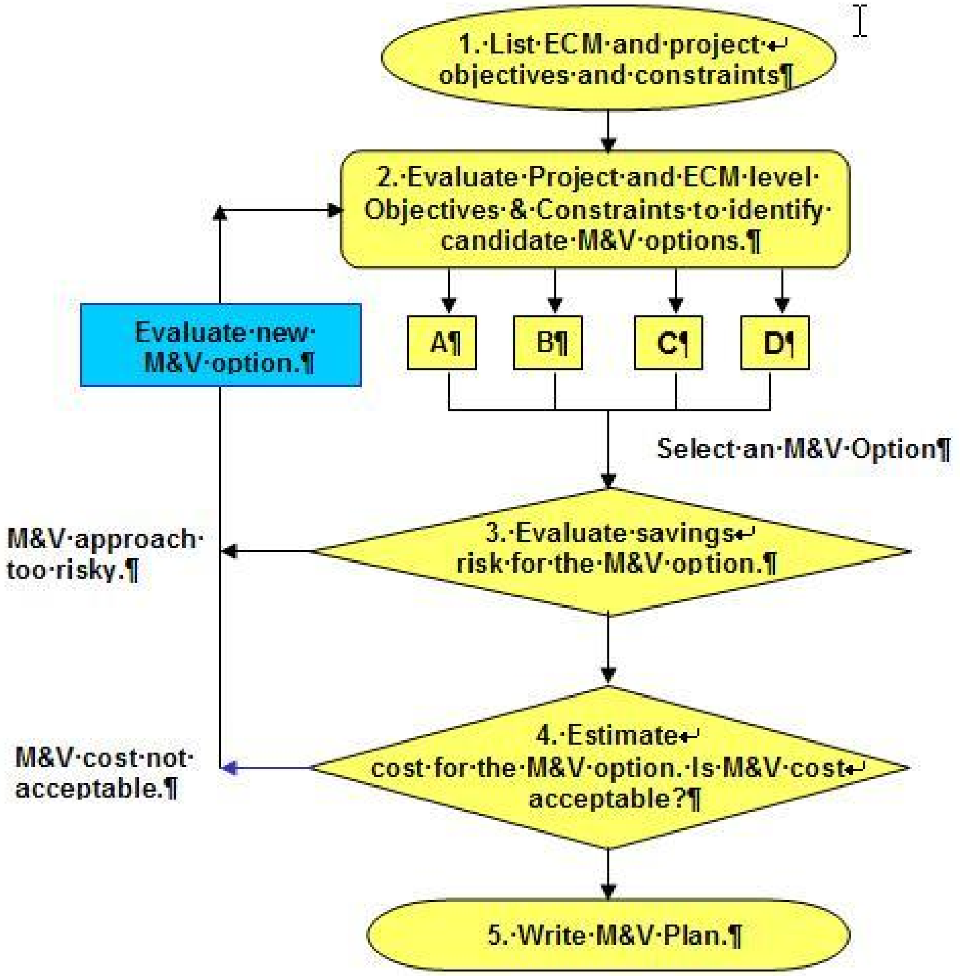
Sufficient work should be done in preparing the M&V Plan so that all parties (in particular the financiers) accept the risks and the expected quality and credibility of the outcomes of the saving determination processes defined in the M&V Plan.

How to develop an M&V Plan

The information in this Section is based on the "FEMP Planning Tool" prepared for users of the FEMP M&V Guidelines Version 2.2.

The tool provides a simple, flexible and customisable framework to help in the development of M&V Plans, by introducing M&V specific issues at an early stage in the project development. The centre piece of the Planning Tool is a flow chart (Figure 3.1).

Figure 3.1 M&V Planning Flowchart



It shows an iterative process commencing with the development of a list of project-level and ECM specific objectives and constraints for the specific project and ECMs. During the iterative planning process the user must start with both project level and ECM specific objectives and constraints and find the best M&V Option (method) that satisfies both sets of objectives and constraints. Details about the selection of the most appropriate M&V Option for each ECM are discussed in Chapter 4.

The M&V Plan is finalised when both the level of risk for the selected M&V method and the associated costs are acceptable. Issues about balancing savings risks and M&V costs are discussed in Chapter 7.

The steps described below correspond to the step numbers on the flow chart.

Step 1: Develop a list of project and ECM objectives and constraints that relate to measurement and verification of savings.

Some typical objectives and constraints for M&V are listed below. A custom list should be developed for the specific project based on key topics that will affect the M&V plan for the project and/or ECMs.

Typical objectives

- Desire to use utility metering data
- Desire to verify energy performance continuously
- Desire to verify energy performance annually
- Track post-retrofit consumption and adjust baseline for changes
- Maximize expenditure on ECM by using least-cost M&V option

Typical constraints

- Historical utility data not available
- Lack of dedicated utility meters
- High degree of interaction between ECMs
- ECM's scope affects a very small portion of overall utility baseyear energy

It is appropriate to include objectives and constraints that may apply, even if enough information is not yet available. A priority (High, Medium, or Low) can be assigned to each Objective & Constraint to help with the evaluation. High priority Objectives and Constraints have the strongest influence on M&V selection and should be considered most imperative in the evaluation.

Step 2: Evaluate project and ECM level objectives and constraints to identify the most appropriate M&V Option. Determine if a single M&V Option can be used for the entire project or if a more custom M&V approach is required for the proposed set of ECMs.

Select an M&V Option for evaluation (Options A, B, C, or D) as described in Chapter 4.

If one of the project level objectives or constraints is not met, select another M&V Option for evaluation. If none of the M&V Options can satisfy the project level objectives and constraints, select and evaluate another M&V Option for the first ECM.

Step 3: Evaluate the savings risk associated with the selected M&V Options.

A custom list of risk elements should be developed based on project and ECM specifics. A "Responsibility Matrix" is provided in the FEMP M&V Guidelines Version 2,2, Section I Chapter 2 to assist users in identifying risk elements for the savings determination processes and the sharing of risks between the facility owner/manager and the contractor (ESCO).

Typical risk elements

- Stipulated ECM performance or operation (refer to Chapter 4)
- Operating hours
- Environmental/process loads
- Degradation of savings
- Weather
- Building occupancy
- Major changes to the facilities
- Savings risk associated with the performance of O&M, repair & replacement

If the savings risk is not acceptable, a new M&V Option should be selected.

Step 4: If one M&V Option has been selected for all ECMs, estimate the cost of using this M&V Option in relation to savings risks. If a custom approach is being followed for individual ECMs, repeat Steps 3 and 4 for each ECM until an M&V Option has been associated with each ECM. Then, estimate the cost of using the selected M&V Options

Do the requirements and the savings risk justify the M&V expenses? If not, return to Step 2.

Step 5: If all the M&V requirements are met and the savings risk justifies the M&V expenses, proceed with the development of the M&V plan for the project.

M&V Plan requirements

An M&V Plan should include the following (adapted from the list provided in Section 3.3 of IPMVP 2001 (March 2002))

- A description of the ECM and its intended result
- Identification of the "measurement boundary". The nature of any energy effects beyond the boundaries should be described and their possible impacts estimated.
- Documentation of the facility's baseyear conditions and the resultant baseyear energy data. The extent of information to be recorded is determined by the boundaries or scope of the savings determination. The baseyear documentation typically requires well documented audits, surveys, inspections and/or spot/short-term metering activities. Where the Whole Facility Option C approach (refer to Chapter 4) is used all building equipment and conditions should be documented. This information may include
    - energy consumption and demand profiles
    - occupancy type, density and periods
    - space conditions or plant throughput for each operating period and season.
    - equipment inventory: nameplate data, location, condition
    - equipment operating practices (schedules, set-points, actual temperatures /pressures)
    - significant equipment problems or outages
- Identification of any planned changes to conditions of the baseyear
- Identification of the post-retrofit period. This may be a short-term test after commissioning of an ECM or as long as the time it takes to recover the investment cost of the ECM project
- Establishment of the set of conditions to which all energy measurements will be adjusted. The conditions may be those of the post-retrofit period, the pre-retrofit period or some other set of fixed conditions
- Documentation of the design intent of the ECM(s) and the commissioning procedures that will be used to verify successful implementation of each ECM.
- Specification of which M&V method will be used to determine energy savings.
- Specification of the exact data analysis procedures, algorithms and assumptions. For each mathematical model used, report all of the terms and the range of independent variables over which it is valid.
- Specification of the metering points, period(s) of metering, meter characteristics, meter reading, meter commissioning, routine calibration process, and method of dealing with missing/erroneous data.
- For Option A (refer to Chapter 4), document details of any stipulated parameters. Show the overall significance of these parameters to the total expected saving and describe the uncertainty inherent in the stipulation.
- For Option D (refer to Chapter 4), document details (name and version number) of simulation software. Provide details of input files, output files, weather reference files, measurements, assumptions and calibration accuracy.
- Specification of quality assurance procedures
- Quantification of the expected accuracy of measurements, data capture and analysis. Also, describe qualitatively the expected impact of factors affecting the accuracy of results that cannot be quantified.
- Specification of the data that will be available for independent verification of reported savings.
- Where the nature of future changes can be anticipated, define methods for making the relevant Baseline Adjustments (Refer to Chapter 5).
- Definition of the budget and resource requirements for the savings determination, both initial setup costs and on-going costs throughout the post-retrofit period.

Sample M&V Plan Outline

An sample M&V Plan Outline is presented in Appendix 2. It has been adapted from The M&V Plan Outline prepared for use by U.S. Federal Agencies participating in the Federal Energy Management Program.

The original M&V Outline Plan is available at http://ateam.lbl.gov/mv/ together with other supporting explanatory information.

The following are additional examples of M&V Plans that may assist users of this Guide to further understand M&V Planning and/or to participate in M&V planning

1. IPMVP Volume I (March 2002): Typical contents of an M&V Plan for each of the four M&V Options are presented in Appendix A.
2. FEMP Sample M&V Plans for SuperESPC Projects

Who should prepare the M&V Plan?

The M&V Plan is an important tool for contractors, customers and financiers to further their common understanding, trust and confidence in the achievement of the expected savings. The Plan highlights the issues that have to be managed in the post-retrofit period, such as facility, equipment and/or operational changes, that may affect the achieved level of savings and require agreement on the amount, time and period of adjustments to the Baseline Energy use to compensate for the impact of the changes on the measured Post-Retrofit Energy use.

For an energy saving project using an external contractor, it is normal practice for the contractor to prepare the M&V Plan in consultation with the facility owner/manager. The owner/manager could prepare the M&V Plan but normally does not have the skills or experience. If required, a third-party M&V practitioner may be used to provide independent advice to both parties.

For in-house energy savings projects, the facility owner/manager can prepare the M&V Plan or use the services of an M&V practitioner.

M&V adherence

It is not sufficient to rely on a broad undertaking in an M&V Plan that the savings determination processes adhere to the IPMVP, the other referenced Guidelines or this Guide. Details about adherence claims have to be referenced to the specific parts of this Guide or referenced to specific parts of the IPMVP, ASHRAE Guideline 14-2002 or the FEMP Guidelines. Adherence has to be demonstrated and documented in the savings reports.

Adherence with this guide

This Guide is not written as a practitioner's guide to M&V nor as a specific application of the IPMVP, as is the FEMP M&V Guidelines for U.S. Federal Agencies.

This Guide should be used as the primary reference for M&V Plans and M&V activities in Australia. Adherence to this Guide should be done by referencing the specific parts of the Guide.

The Guide will be updated from time to time to reflect the continuing improvements to the content of the Guide. The references should be made to the latest version of this Guide (visit the AEPCA website for update to this Guide).

This Guide derives its authority and relies on the information in

- IPMVP Volume 1 (March 2002) and provides references to specific parts of the IPMVP Volume 1 (March 2002).
- ASHRAE Guideline 14-2002
- U.S. Federal FEMP M&V Guidelines Version 2.2

If M&V Plans and activities are based on additional detailed information available in the above referenced documents, detail references should be provided to the parts of the documents that are referenced.

Essentials for Adherence

The essentials for adherence to this Guide are:

1. **There must be an agreed M&V Plan that is followed**
2. **One of the four (4) M&V Options must be selected, specified and followed**
3. **The accuracy and confidence level of savings must be reported**
4. **All M&V matters must be documented so an independent person (who has not been involved in determining the reported savings) can verify the reported savings.**

Who should verify M&V Plan adherence?

The general principle is the same as for quality assurance: person(s) independent of the person(s) who planned and implemented the M&V Plan should verify the savings outcomes and adherence to the M&V Plan.

The normal practice is as follows:

- The M&V activities are planned and implemented by the contractor, with agreement from the facility owner/manager.
- The reported savings and adherence to the M&V Plan are verified by the facility/owner manager.

A third-party M&V practitioner may be used to provide independent advice to both parties on the verification of the savings outcomes and adherence to the M&V Plan.

What you should remember about M&V planning

- Preparation of an M&V Plan is central to proper savings determination and is the basis of verification.
- The M&V plan defines project-specific and ECM-specific M&V methods for determining the savings.
- The initial M&V Plan should be prepared as soon as possible during the project feasibility and definition stage and then it should be iteratively refined until all parties can sign off on the M&V Plan.
- The M&V planning process will help find a balance between savings risks and costs within the objectives and constraints of your project and ECMs.
- The draft M&V Outline Plan can be used as a starting point for preparing project-specific and ECM-specific M&V Plans.
- The quality and completeness of the M&V Plan will determine how well the reported savings are determined and how they can be verified.
- Quality management principles should be used to manage the independence and verifiability of the savings outcomes and the M&V.
- This Guide should be used as the primary reference for M&V Plans and M&V activities in Australia.
- Adherence to this Guide should be made by referencing specific parts of the Guide.

CHAPTER 4: SELECTING M&V OPTIONS

"If you don't have a methodology - don't expect credible results"

Background

The general methodology for savings determination is to measure the baseyear and post-retrofit energy uses and then to adjust the baseyear measurements to the post-retrofit conditions. For the simplified scenario presented in Chapter 2, the savings determination method was reasonably simple. There was only one meter measuring energy consumption of an isolated energy subsystem in a facility with a stable operational history, well maintained equipment, and very little change expected in the future. Energy consumption for periods before and after the retrofit were measured and savings were calculated by subtracting actual measured post-retrofit energy consumption from the baseyear energy consumption adjusted to post-retrofit conditions (Baseline Energy). Details of how the adjustment was defined and calculated were not discussed. These issues are discussed in this Chapter.

In the real world of energy savings projects there are usually a number of factors affecting the savings determination approach, time, effort and cost, as well as the quality and credibility of the savings outcomes. These factors include

- Number, complexity and technology of the ECMs
- Degree of interaction between multiple ECMs
- Value of estimated savings for each ECM and whether savings are guaranteed
- Accuracy and confidence level with which savings should and can be determined
- Length of the post-retrofit period during which savings have to be determined
- Allocation of risks for achieving savings between the interested parties, including the type and formality of contractual obligations
- Type, availability, and location of meters relative to ECMs, plus the historical and continuing availability of metered data
- Validity and significance of relationships between metered energy data and non-ECM factors that influencing historical and continuing energy consumption
- Historical and continuing availability of data on non-ECM conditions about the site, facility and energy subsystems that could affect the savings effectiveness of each ECM
- Potential for changes in key non-ECM factors, between the baseyear period and the post-retrofit period, which influence energy use
- Cost/benefit and affordability of the M&V relative to the estimated project savings.

This Chapter provides guidance on selecting the most appropriate savings determination approach for a specific energy savings project.

After reading this Chapter you should be able to understandthe appropriateness of the savings determination approach selected and used for your energy savings project.

M&V Options

An M&V Option is an M&V method that can be used to determine savings for a specified common type of ECM.

There are four generic M&V Options – Options A, B, C and D. The savings outcomes produced by the four M&V Options have varying levels of savings uncertainty and M&V costs.(Refer to Table 4.1).

All M&V Options are based on the same concept of determining savings by comparing energy use measured after the retrofit to the estimated post-retrofit energy without the retrofit.

A particular Option should be chosen based on the project-specific features of each energy savings project. Each Option has advantages and disadvantages based on project-specific factors and on the expectations and requirements of the specific project.

The two main questions that differentiate the use of the four options are:

1. Are savings to be measured for each ECM or for all ECMs at the whole facility level, and
2. What is the availability, frequency and duration of the baseyear and performance period measurements?

Table 4-1. Adaptation of Table on page 22 of the IPMVP Vol. 1, "Overview of M&V Options"

IPMVP Options	IPMVP Name	How Savings Are Calculated	Common Use
Option A	Partially Measured Retrofit Isolation	Engineering calculations using short term or continuous post-retrofit measurements and stipulations	For a single ECM where the performance of the ECM can be measured but it may be best to stipulate it's operation.
Option B	Retrofit Isolation	Engineering calculations using short-term or continuous measurements	For a single ECM where the performance and operation of the ECM should be measured
Option C	Whole Facility (Building)	Analysis of whole facility or building utility meter or sub-meter data, available continuously, using techniques from simple comparison to regression analysis	For single ECM or multiple ECMs with or without energy interactions within a whole facility or building. Energy use is measured by utility meters for at least 12 months of the baseyear and continuously throughout the post-retrofit period
Option D	Calibrated Simulation	Energy use simulation, calibrated with hourly or monthly utility billing data and/or end-use metering	For a single ECM or multiple ECMs with or without energy interactions within a whole building but where no baseyear data are available. Post-retrofit measurements are used to calibrate the simulation model. Baseyear energy use and demand are generated by the simulation model.

Retrofit Isolation and Whole Facility Options

The first decision in selecting an M&V Option is whether a "Retrofit Isolation" or a "Whole Facility" method should be used. The main differentiating factors between the two types are as follows:

Retrofit Isolation methods look only at the equipment or system affected by the ECM, independent of the rest of the equipments or systems in the facility. Savings are determined for each ECM i.e. at the ECM-level

The measurement boundary for these M&V methods is around the equipment or system being retrofitted with an ECM. The term "retrofit isolation" simply means that the energy use for the equipment or system being "retrofitted" is isolated from other energy uses.

Option A and Option B are "Retrofit Isolation" methods. Option D can be used as a "retrofit isolation" method but is normally used as a "whole facility" method.

Whole Facility methods consider the total energy use for the "whole facility" and ignore the energy use of each individual equipment or system being retrofitted. Savings are determined for the "whole facility" – not for each ECM.

The measurement boundary for these M&V methods is at the facility or site level depending on the level the measurements can be taken.

- If the ECMs are spread over a number of facilities/buildings in a site and there is a (utility) meter that measures the energy supplied to the whole site, the measurement boundary is at the site level.
- If there are multiple ECMs in one facility/building on a site and a meter is available to measure the energy supplied to this facility/building, the measurement boundary is at the facility/building level.

A "whole facility" method has to be used when it is not feasible or practical to isolate the effects for each ECM, usually because of energy interactions between the ECMs

Option C is the main "whole facility" method that uses utility metering as the source of the measurement data. Option D is normally used as a "whole facility" method.

Option A: Partially Measured Retrofit Isolation

Option A is used at the individual retrofit or system level. It is commonly used for specific ECMs involving retrofitting of specific components such as lighting, motors, variable speed drives, and chillers.

The fundamental factors that drive energy savings are changes in "performance" (efficiency, capacity, demand, power, etc) and/or "operations" (usage, lighting operational hours, etc). For example, savings for a lighting retrofit could be achieved by using more efficient lamps to reduce the watts required to provide a specific amount of light (change in performance factor), and/or by using lighting controls to reduce the operating hours (change in operations factor).

Option A is mainly intended for retrofits where either "performance" or "operations" factors can be spot or short-term measured before and after the retrofit and the other factor can be stipulated (not measured)

It is intended for projects in which the potential to generate savings must be verified , but the actual savings can be determined from short-term data collection, engineering calculations, and stipulated factors. Post-retrofit energy use is not measured throughout the post-retrofit period. Post-retrofit and baseyear energy use is estimated using an engineering or statistical analysis of information that does not involve long-term measurements.

All end-use technologies can be verified using Option A but the accuracy of Option A is generally inversely proportional to the complexity of the ECM. For example, Option A will typically estimate more accurately the savings from a simple lighting retrofit than from a chiller retrofit. If greater accuracy is required, Options B, C or D may be more appropriate.

Savings are determined by measuring the capacity, efficiency or operation of a system before and after the retrofit and by multiplying the difference by a stipulated factor. While stipulated values are usually easier and less expensive to derive, stipulations are typically the least accurate method and contribute the greatest uncertainty to the savings estimate.

Using stipulated values for determining savings can be a practical and cost-effective way to minimise costs. It is allowable to stipulate rather than measure some parameters for the savings calculation. However, stipulation can only be made where it can be shown that the combined impact of the likely errors from such stipulations will not significantly affect the overall reported savings. Some but not all parameters of energy use may be stipulated.

Savings cannot be fully stipulated by stipulating both the performance and operations factors of a retrofit.

The decision on which parameters to measure and which to stipulate should consider the significance of all the stipulations on overall reported savings. Stipulation may be based on historical data recorded during the baseyear and should be based on reliable, traceable, and documented sources of information. Engineering estimates or mathematical modelling may be used to assess the significance of stipulating any parameter in the reported savings. The stipulated values and analysis of their significance should be included in the M&V Plan.

The decision to measure or stipulate a factor should consider any potential impacts on risk sharing for the achievement of the savings. Where a factor is significant to assessing a contractor's performance it should be measured, while other factors beyond the contractor's control should be considered for stipulation. **Savings determination without stipulations leaves the risk with the contractor. The facility owner/manager assumes the risk for the factors that are stipulated**. If these contribute to overstating or understating savings, the facility owner/manager has to accept the determined savings.

Using stipulated values in savings estimates is appropriate if some or all of the following apply

- The ECM has a high probability of delivering the expected savings, it contributes a small percentage to the overall project savings and to the overall project uncertainty.
- The facility owner/manager is willing to accept the savings risk and/or has experience with similar ECMs.
- The contractor has no control over the factor (e.g. operating hours).
- The cost of measurement is not justified by the value of the reduced uncertainty or cannot be justified for other uses

The savings calculations for Option A are engineering-based and use the stipulated factor and the changes in the non-stipulated performance or operation factor.

Option A Savings Calculation with Stipulated Operations Factor

The form of the savings calculation when the operations factor is stipulated is of the type

Energy Savings =
((Performance Factor) **Before Retrofit**
–– (Performance Factor) **After Retrofit** **)**
X Stipulated Operations Factor

This type would be used for a lighting efficiency retrofit where the ECM objective is to reduce the amount of power required to provide the required illumination. The savings calculation would be:

Energy Savings =
((kW/Fixture x No of Fixtures) **Before Retrofit**
–– (kW/Fixture x No of Fixtures) **After Retrofit** **)**
X Stipulated Number of Operating Hours

Stipulating number of operating hours would be appropriate for an energy retrofit to a military barracks or to a youth camp where there is intermittent occupation of the building. In this situation, the contractor would have no control of the operating hours. It would be appropriate for the camp owners/operators to accept the risk of stipulating the operating hours. The saving guarantee would be based on the contractor using wattage and calculations to demonstrate that the lighting efficiency for the required illumination had been improved.

If there were no changes in the number of fixtures the savings verification would be based solely on using wattage measurement and calculations to demonstrate the retrofitted lamps were more efficient.

Option A Savings Calculation with Stipulated Performance Factor

The form of the savings calculation when the performance factor is stipulated is of the type

Savings =
((Operations Factor) **Before Retrofit**
- (Operations Factor) **After Retrofit** **)**
X Stipulated Performance Factor

This type of savings calculations would be used for a lighting control retrofit using occupancy sensors where the ECM objective is to reduce energy by reducing the number of hours the lights are on, without inconveniencing the occupants of the building.

Savings =
((Number of Operating Hours) **Before Retrofit**
–– (Number of Operating Hours) **After Retrofit** **)**
X Stipulated (kW/Fixture x No of Fixtures)

Stipulating lighting wattage and measuring operating hours would be appropriate when energy efficient lighting is already installed and there are spaces/rooms that are not always occupied but lights are left on.

For schedule-based lighting controls, such as time clocks, it would be appropriate to stipulate the operating hours and to take shot-term measurements of the lighting wattage.

Option A – M&V Guidelines

General guidance on Option A is provided in Section 3.4.1 of the IPMVP Volume 1 (March 2002) with an example in Appendix A. Detailed guidelines on Option A are provided in Section III Chapters 6 to 11 of the FEMP M&V Guidelines Version 2.2. The FEMP M&V Guidelines for Option A were updated in March 2002 for closer compliance and alignment with the IPMVP Volume 1 (March 2002). The updated document is available at http://ateam.lbl.gov/mv/.

The previous FEMP M& V Guidelines for Option A allowed full stipulation of savings. The updated version restricts the use of full savings stipulation. The updated version explains circumstances when it still may be acceptable to use full stipulation – when the savings uncertainty caused by the stipulation is relatively small and the level of savings is very small.

As explained in Chapter 10, it may be appropriate to stipulate both performance and operations factors for incentive and/or rebate type energy savings projects, designed for small energy savings over a large number of small projects, and where the M&V cost has to be very small. An example is a rebate or incentive scheme targeted at small business or residential users, where the individual project savings would be small but there would be many projects. In this case a fully stipulated M&V method may be justifiable.

Appendix 3 of this Guide has a list of M&V methods described in the FEMP M&V Guidelines Version 2.2 for various types of end-use technology retrofits. For the Option A, they cover the following types of ECM technologies:

- Lighting Efficiency retrofits
- Lighting Controls
- Constant Load Motors
- Chiller retrofits

It should be noted that the ASHRAE Guideline 14-2002 does not allow any form of stipulation when measuring and verifying energy and demand savings.

Option B: Retrofit Isolation

Option B is similar to the Option A except that no stipulations are allowed and measurements are made periodically or continuously. **Option B is a fully measured retrofit isolation method.** It is used for specific ECMs involving retrofits to specific components, sub-systems or systems. Option B involves isolation of the energy use of the equipment affected by the ECM.

It is mainly intended for retrofits to performance factors (e.g. end-use capacity, demand, power) and operational factors (e.g. lighting operational hours, cooling ton-hours) that can be measured at the component, subsystem or system level. It is appropriate to use spot or short-term measurements to determine savings when variations in operations are not expected to change. When variations are expected, it is appropriate to measure factors continuously during the performance period. Continuous metering should be used when continuing variations are expected. Also, continuous measurement can provide long-term data on energy performance, which can be used to optimise operation of the equipment and further benefit the retrofit savings.

Performing continuous measurements (which could be periodic) during the performance period, accounts for operating variations and will improve the accuracy of the reported energy savings. Measurement of all affected pieces of equipment 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.

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

- For simple equipment replacement projects with savings that are less than 20% of the total facility energy use as recorded by a relevant utility meter or a sub-meter.
- When energy savings per individual ECM are required
- When interactive effects are to be ignored or are stipulated using estimating methods that do not involve long-term measurements.
- When the independent explanatory variables that affect energy use are not complex, excessively difficult or expensive to monitor
- When sub-meters already exist that record energy use of sub-systems or systems that are to be retrofitted.

Savings created by most types of ECMs and all end-use technologies can be determined with Option B. However, the degree of difficulty and costs associated with verification increases as metering complexity increases. The task of measuring or determining energy savings using Option B can be more difficult and costly than for Option A, but the results are typically more accurate, especially where there is significant variation in operations.

Option B Savings Calculation

The savings computations for Option B are generally of the following type.

Savings =
(Performance x Operations) $_{\textbf{Before Retrofit}}$
- (Performance x Operations) $_{\textbf{After Retrofit}}$

For a lighting efficiency retrofit example this may equate to:

Savings =
(kW/Fixture x No of Fixtures
x Operating Hours) $_{\textbf{Before Retrofit}}$
- (kW/Fixture x No of Fixtures
x Operating Hours) $_{\textbf{After Retrofit}}$

Option B – M&V Guidelines

General guidance on Option B is provided in Section 3.4.2 of the IPMVP Volume 1 (March 2002) and an example is provided in Appendix B of IPMVP. Detailed guidelines on Option B are provided in Section IV Chapters 12 to 20 of the FEMP M&V Guidelines Version 2.2.

Detailed procedural and technical guidance on the use of the Retrofit Isolation for various types of end-use technologies is provided in Section 6.2 and Appendix E of ASHRAE Guideline 14-2002. This is for Option B as the ASHRAE Guideline does not allow Option A stipulation.

Appendix 3 of this Guide has a list of the M&V methods described in the FEMP M&V Guidelines for various types of end-use technology retrofits.

- Lighting Efficiency: Monitoring Operating Hours and Metering Lighting Circuits.
- Lighting Controls: Monitoring Operating Hours and Metering Lighting Circuits
- Constant-Load Motor Efficiency: Metering Operating Hours
- Variable-Speed Drive Retrofit: Continuous Post-Installation Metering
- Chiller Replacement: Metering of kW, and of kW and Cooling Load
- Generic Variable Load: Continuous Post-Installation Metering

Option C: Whole Facility (Building)

Option C involves use of continuous measurement data from utility meters or whole building sub-meters and/or regression modelling to determine energy savings for the total site, facility or building, depending on the location of the metering point. This Option involves collecting historical whole-facility energy use and the continuous measurement of whole-facility post-retrofit energy use. Energy savings are estimated by statistically representative models of whole-facility energy consumption or by performing simple utility bill comparisons.

In general, Option C should be used with complex equipment replacement and controls projects for which predicted savings are relatively large. Option C should be used in cases where there is a high degree of interaction between installed ECMs or between ECMs and the rest of the facility, or when the isolation and metering of individual ECMs is difficult and costly.

Option C determines the collective savings of all ECMs applied to a facility which has energy use measured by a meter. It assesses the impact of any type of ECM, but not individually, if more than one type of ECM is applied to that energy meter. Also, since whole-facility meters are used, savings reported under Option C include the impact of any other non-ECM factors influencing the measured energy use.

This Option is intended for projects where savings are expected to be large enough to be differentiated from the random or unexplained energy variations that are normally found at the whole-facility level. The larger the savings, or the smaller the unexplained variations in the baseyear, the easier it will be to identify savings with a high degree of accuracy and confidence. **Typically, Option C should be used when the expected savings are greater than 10% of the baseyear energy use.**

With Option C, accounting for non-ECM changes affecting measured post-retrofit energy use is the major challenge. It is particularly important to document non-ECM conditions during the baseyear period and then to regularly check for any changes during the post-retrofit period. If there are material changes to the assumed baseyear conditions, Baseline Adjustments (refer to Chapter 5) have to be made.

The routine adjustment (refer to Chapter 5) term of the savings equation is calculated by developing a valid model of each meter's baseyear energy use. The model can be a simple bill-matching model (with no adjustment factors) replicating the measured data for all the baseyear billing periods as the best estimate of the Baseline Energy use for all corresponding post-retrofit billing periods. A "bill matching" model is valid when no non-ECM factors, such as weather or occupancy, influence energy use measured during the baseyear.

The most common Option C model is derived from regression analysis by correlating energy use with one or more independent explanatory influence variables, such as weather severity,, occupancy or building operating mode. In certain facilities where there is a significant difference between the facility's energy use during a period (for example during the school year and holidays), separate regression models may need to be developed for the different usage periods.

The Option C method for creating statistically valid whole-facility models by regression analysis is discussed in detail in Appendix 5, together with an example.

The basic procedural and calculation steps are as follows and are illustrated in Figure 4.1:

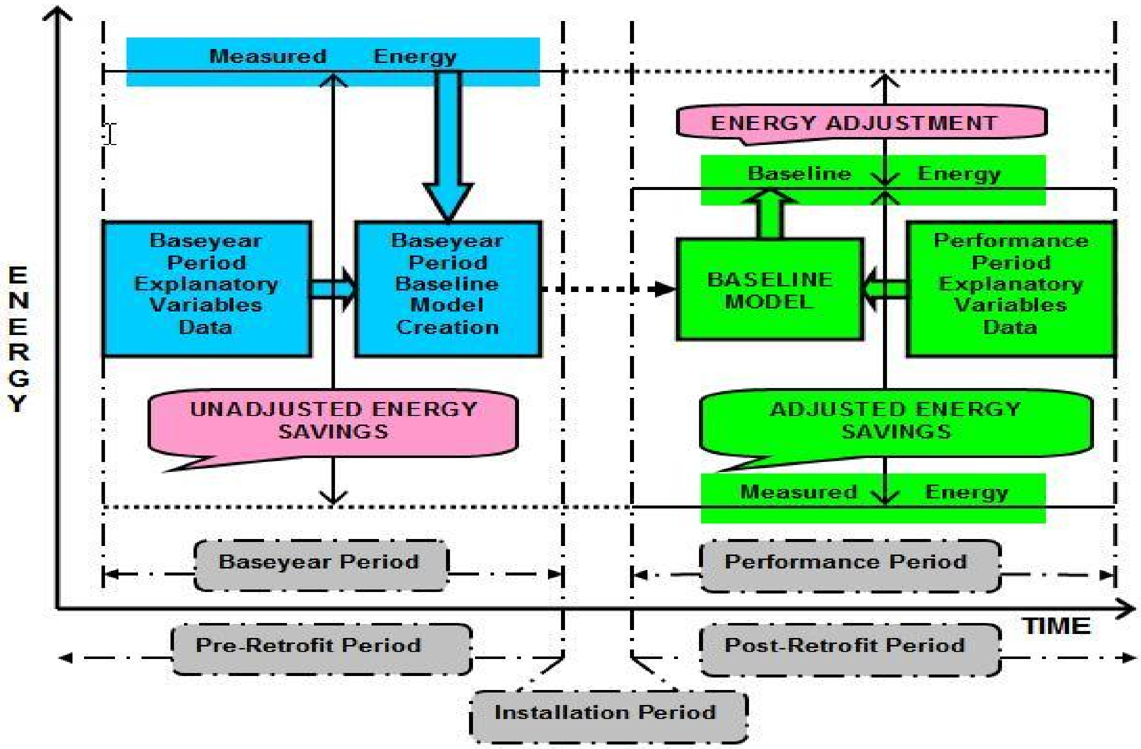
- Develop an appropriate Baseline Model for the baseyear period that represents the normal baseyear operation. This is done by performing a multivariate regression analysis of the baseyear energy use and selected statistically significant explanatory variables. (Refer to Appendices 4 and 5 for details on establishing the statistical significance of the Baseline Model and the selected explanatory variables)
- Use the Baseline Model and the post-retrofit explanatory variables to calculate the Baseline Energy in the post-retrofit period
- Calculate savings by taking the difference between the Baseline Energy and the measured Post-Retrofit energy use.

<u>Option C – M&V Guidelines</u>

General guidance on Option C is provided in Section 3.4.3 of the IPMVP Volume 1 (March 2002) and an example is provided in Appendix C of IPMVP. Detailed guidelines on Option C are also provided in Section V Chapters 21 to 23 of the FEMP M&V Guidelines Version 2.2. Further procedural and technical details on the using Option C are available in ASHRAE Guideline 14-2002 Sections 6.1, and Annex D

Appendix 3 of this Guide lists Option C methods described in the FEMP M&V Guidelines.

Figure 4.1 Savings Calculation processes using Option C regression analysis



Option D: Calibrated Simulation

Option D uses computer simulation software to predict facility energy use for the baseyear and/or post-retrofit period. The simulation model must be calibrated so that it predicts an energy use pattern that reasonably matches actual utility consumption data from either the baseyear or a post-retrofit year.

Similar to Option C, Option D may be used to assess the performance of all ECMs in a facility. Like Options A and B, Option D may also be used to assess just the performance of an individual equipment, subsystem or system within a facility. In this case, the calibration data and any ongoing measurement must be obtained from meters that isolate the energy use of the individual system from the rest of the facility.

Option D is most useful when the baseyear data does not exist or are unavailable. This situation may occur for a new facility with ECMs that have to be assessed separately from the rest of the facility. It may also occur where there are no facility sub-meters to provide baseyear data but these meters will be available during the post-retrofit period. Option D can also be used when the post-retrofit measurement data is unavailable or where the impact of non-ECM factors can't be quantified with sufficient accuracy and confidence to estimate Baseline Adjustments.

Option D should be used instead of Option C when the expected savings are not large enough to be separated from variations in the facility's utility meter data. Option D may also be used when the savings for individual ECMs have to be determined but the Option A or B isolation approach is too difficult or costly.

This Guide does not deal with Option D as it is not used very often for M&V of energy retrofits, as it requires the services of a trained energy simulation specialist. It may be used by energy engineers during investigation of the savings potential of ECMs and during the design phase of an energy savings project.

Option D – M&V Guidelines

General guidance on Option C is provided in Section 3.4.4 of the IPMVP Volume 1 (March 2002) and an example is provided in Appendix D of IPMVP. Detailed guidelines on Option D are provided in Section VI Chapters 24 to 25 of the FEMP M&V Guidelines Version 2.2. Further procedural and technical details on the using Option D are available in ASHRAE Guideline 14-2002 Sections 6.3, and Annex B.7

Appendix 3 of this Guide lists Option D methods described in the FEMP M&V Guidelines.

Selection guidelines for M&V Options

Each project is different. Each situation should be analysed, including costs relative to the estimated savings, and desired accuracy.

Table 4-2 shows factors that should be considered when selecting the most appropriate M&V Options.

The information is an adaptation of information presented in Table 5-2 and Table 5-4 of ASHRAE Guideline 14-2002 for Options B, C, and D, and similar comparative information presented at the Certification and Measurement Verification Professional (CMVP) accreditation course on M&V.(Reference Cowan, J).

Table 4-2. Adaptation of Table 5-2 and Table 5-4 of ASHRAE Guideline 14-2002

Considerations in Selecting M&V Options	**A**	**B**	**C**	**D**
Ability to determine savings of individual ECMs	Y	Y	N	Y
Assess at facility or building level	N	N	Y	Y
Savings less than 10% of total consumption	Y	Y	N	Y
Multiple ECMs	N	N	Y	Y
Relationship of influence variables with energy use or demand is unclear	N	Y	Y	Y
Interactive effects between ECMs are significant or not measurable	N	N	Y	Y
Expect many future changes to non-ECM factors within measurement boundary	Y	N	N	Y
Long-term savings determination	Y	N	Y	N
No baseyear data	N	N	N	Y
Need non-technical persons to understand results	Y	Y	Y	N
Have metering and instrumentation skills and experience	Y	Y	N	N
Have simulation skills and experience	N	N	N	Y
Have skills in reading utility bills	N	N	Y	N
Type of ECM Technology	Y	Y	Y	Y

M&V Options for technology-specific ECMs

The selection of an appropriate M&V Option and many of the implementation details are largely determined by the retrofit technology usedto generate energy savings. This Guide has so far focused on the generic four M&V Options as defined in the IPMVP.

ASHRAE Guideline 14-2002 and the FEMP M&V Guidelines Version 2.2 describe details of the savings determination that are most appropriate for technology-specific end-use ECMs such as lighting, constant load motors, variable speed drives, chiller retrofits and others.

Appendix 3 of this Guide presents the list of FEMP Methods for various end-use technologies. Details are provided in the FEMP M&V Guidelines Version 2.2 for each of the FEMP Methods.

Annex E in ASHRAE Guideline 14-2002 presents procedural and technical details of the savings determination processes that are applicable for various end-use technologies.

What you should remember about M&V Options

- An M&V Option describes an M&V method that can be used to determine savings for a specified common type of ECM.
- There are four generic approaches for energy savings determination, which provide a range of approaches for determining savings with varying levels of uncertainty, cost and methodology.
- Options A and B are used if your ECM is about improving the efficiency or operation of end-use equipment.
- Option C should be used when you have more than one ECM and you can't separate out their individual savings contribution and ECM interactions.
- Option D should be used when no measurement data is available. It is not used very often for M&V as it requires the services of an energy simulation specialist
- Each project and each ECM is different. Each situation should be analysed including costs relative to estimated savings and desired accuracy.

CHAPTER 5: ROUTINE AND BASELINE ADJUSTMENTS

"Be prepared for adjustments - Murphy's Law is omnipresent"

Background

The M&V Options in Chapter 4 describe the four generic approaches to determining overall savings. As explained in Chapter 2, the generic savings calculation method is based on creating the Baseline Energy in the post-retrofit period by making "adjustments" to the baseyear energy measurements for changes in the post-retrofit conditions, and then taking the difference between the calculated Baseline Energy and the actual Post-Retrofit Energy. The general savings equation is as follows.

Savings = Baseline Energy
– Post-Retrofit Energy

where

Baseline Energy = Baseyear Energy
+ Routine Adjustments
+Baseline (Non-Routine) Adjustments

The Adjustments term in the savings equation is calculated in two separate parts:

- Routine Adjustments
- Baseline (Non-Routine) Adjustments

Routine Adjustments

Routine Adjustments are made for predictable changes in non-ECM conditions between the baseyear and the post-retrofit periods. Non-ECM factors most often used for routine adjustments are seasonal or cyclical, such as weather, occupancy, operating hours or production level variations. Routine adjustments are made for non-ECM factors

- that can be expected to continue influencing energy use or throughout the post-retrofit period, and
- for which a specific relationship can be identified and predetermined, before the ECM installation, on how these specific non-ECM factors influence energy use over time.

The calculation methods described for the four M&V Options in Chapter 4 are Routine Adjustment calculation methods. Taking Option C as an example, once the Baseline Model is agreed to as being statistically significant, it will be used to "routinely adjust" the Baseyear Energy so that the Baseline Energy always reflects the prevailing post-retrofit conditions for the selected explanatory variables in the Baseline Model.

Details of routine adjustment calculation methods, including specification of the exact data analysis procedures, algorithms and assumptions, must be pre-defined in the M&V Plan and agreed by the interested parties. The savings calculation must be done in accordance with the details of the agreed pre-defined method and any deviations, including changes to assumptions, must be documented for the scrutiny of others.

Baseline (Non-Routine) Adjustments

The circumstances and calculation methods for making Baseline (Non-Routine) Adjustments are quite different from those for routine adjustments. Baseline Adjustments are made for unpredictable changes in non-ECM conditions The only real criteria of whether a Baseline Adjustment should be made is that both parties agree on the amount, timing and period of the adjustment. There are no real limitations on the calculation methods and processes used for Baseline Adjustments.

An example of the need to make a Baseline Adjustment is when a major water leak causes an unpredictable short-term increase in water consumption The contractor would be disadvantaged as the increased consumption would manifest itself as a reduction in savings. Because the leak was outside the control of the contractor, an agreed Baseline Adjustment would be made so that the level of savings would not be impacted.

The quality, acceptability and correctness of reported savings depend on the proper use of Routine Adjustment calculations associated with the M&V Option and the management of the unpredictable Baseline Adjustments.

Importance of routine adjustments to reported savings

The quality and credibility of reported savings is affected by the selection, execution and documentation calculation methods used for the routine adjustments. Everyone can accept the reality of energy measurements as they are obtained using physical meters and instruments, even though the technology and mathematics used in the meters and instruments may not be understood.

A routine adjustment calculation uses a defined computational method to adjust the real baseyear measured data into the post-retrofit Baseline Energy.

The computational methods used to calculate Baseline Energy values use mathematical estimation techniques and algorithms ranging from relatively simple to relatively complex. The quality and credibility of the calculated savings depend mainly on

- the appropriateness of the selected computational method
- the knowledge, skills and experience of those responsible for calculating the savings
- the discipline and transparency of the computational processes
- the handling of uncertainties in the available data and those inherent in the selected computational process.

Statistical methods are used for some of the computational methods and for estimating uncertainty in the reported savings. Detailed knowledge about these mathematical and statistical methods is not required for understanding reported savings.

Measurement data has inherent errors (e.g. meter inaccuracy and sampling limitations) and the computational processes invariably introduce additional errors (e.g. modelling limitations). Reported savings should always be quoted with a level of accuracy and confidence level.

Reported Savings are always "estimated" quantities because they are the difference between the "estimated" Baseline Energy values and the measured Actual Energy values in the post-retrofit period.

The ultimate objective of this Guide is to maximise the accuracy and confidence level in reported savings within an acceptable cost for M&V (Refer to Chapter 7).

Baseline Adjustments

In this Guide, the term "Baseline Adjustments" refers only to non-routine adjustments. This conforms with the definition of the term in the IPMVP Volume 1 Section 6.1, which states that Baseline Adjustments are "the non-routine adjustments arising during the post-retrofit period that cannot be anticipated and which require custom engineering analysis". The above use of the term is also generally in accordance with the use of the term in ASHRAE Guideline 14-2002, Sections 5.2.8.3 and 6.1.3.6.

Routine adjustments use a Baseline Model or some equivalent form of calculation to transform baseyear energy to estimated Baseline Energy in the post-retrofit period. The estimated Baseline Energy is valid only if other baseyear conditions, not accounted for in the routine adjustment calculations, continue during the post-retrofit period.

Baseline Adjustments are additional adjustments made to the Baseline Energy for unexpected changes, during the post-retrofit period, in any of the assumed baseyear conditions that materially affect the validity of the Baseline Energy.

However, the traditional use of the term "Baseline Adjustments" includes both routine and non-routine adjustments. When it includes both types of adjustments, the term "Baseline Energy" refers to the baseyear energy, before any routine adjustments. Readers should be aware that this wider use of the term is used in the FEMP M&V Guidelines and in other M&V references, including the BPG-EPC. The context within which the term is used will generally make the meaning clear.

Baseline Adjustments are one of the most difficult M&V issues to manage. They are a potential source of conflict if not managed properly. Even though there are difficulties in understanding and accepting routine adjustment calculations, they can be questioned, discussed and defined during preparation of the M&V Plan with "no surprises" when the savings are calculated. In contrast, decisions about Baseline Adjustments have to be made on a contingency basis and managed as a risk.

Concerns about Baseline Adjustments are centred around the uncertainty of what is going to change, when it is going to change and how the impact of the change will be assessed and agreed.

The following are typical Baseline Adjustment issues:

- Which of the many assumed baseyear conditions could change sufficiently during the post-retrofit period to require a Baseline Adjustment?
- Which of the assumed baseyear conditions are most likely to change sufficiently to require a Baseline Adjustment?
- How will a change in the assumed baseyear conditions be detected and judged to be significant?
- What data will be required, what data will be available, and how will the impact be calculated?

These concerns can be managed by using the combined knowledge, skills and cooperation of all the parties to:

- Select the most likely assumed baseyear conditions that could change during the post-retrofit period and that could have a material impact on the Baseline energy
- Document the selected baseyear conditions and continually monitor them for significant changes which could affect the validity of the Baseline energy
- Use the best available data and calculation methods to estimate and agree on the impact of material changes to the Baseline energy.

The only real criteria of whether a Baseline adjustment should be made is that both parties agree.

Importance of Baseline Adjustments

The management of Baseline Adjustments has a major impact on the continuing correctness of reported savings.

The discipline and commitment in preparing and following an M&V Plan and in minimising measurement and calculation errors could be wasted if Baseline Adjustments are not managed properly.

There are benefits to all parties in minimising risks to reported savings from unexpected material changes to the assumed baseyear conditions. If the changes are ignored:

- The reported savings could include savings that are not attributable to ECMs and consequently give benefits to the contractor at the expense of the facility owner/manager.
- Conversely, the reported savings could exclude savings that are attributable to ECMs and consequently disadvantage the contractor to the benefit of the facility owner/manager.

The above are both dependent on the contractual arrangements – if any – for handling shortfalls in expected (guaranteed) savings and/or sharing excess savings.

Whether the savings are guaranteed, promised or just expected, it is in the best interest of all parties to ensure that best endeavours are used by all to minimise gross errors in the reported savings.

Managing changes in Baseyear Conditions

Baseline Adjustments are not needed for

- Changes to explanatory variables included in the Baseline Model
- Changes that affect a variable that was stipulated under Option A in the M&V Plan. Even though the change in the variable affects the actual savings the it does not affect the savings determined by the agreed simplified savings determination method. When there are stipulated conditions and/or influence factors, the facility owner/manager accepts the savings risk for the actual condition and/or factor varying from the agreed stipulations.
- Changes that occur to equipment beyond the "measurement boundary" of the savings determination. For example, if additional appliances are added to a part of the facility outside the defined "measurement boundary" for the ECM. Care should be taken in defining the "measurement boundary" for Options A and B and in ensuring that the retrofit isolation is valid and robust against changes outside the "measurement boundary".

Baseline changes are required when there is a material change to the facility's use or operation. These can occur as a result of

- Physical changes to facilities - renovations, extensions, additions, or closures
- Changes in usage, occupancy, hours of operation, or building activity
- Changes in the amount of space being heated or air-conditioned
- Changes in energy subsystems and end-use equipment/appliances.

- Changes in the amount or use of equipment
- Changes in environmental conditions (lighting levels, set-point temperatures, etc)
- Changes in production throughput, schedules or product mix
- Changes in maintenance practices

Baseyear conditions need to be well-documented in the M&V Plan so that changes can be identified and evaluated. The facility owner/manager usually has intimate knowledge and experience of the most probable conditions affecting the energy performance of the facility. Also, the facility owner/manager should share the best available information about future plans for physical changes to the facility and any other planned changes to usage, operations and maintenance. The contractor will also have gained knowledge about the baseyear energy performance and can contribute to the decisions about which baseyear conditions should be documented.

It is important to have a method of tracking and reporting changes to the assumed conditions during the post-retrofit period either by the facility owner/manager or the party responsible for determining the savings. It should be established in the M&V Plan who will track and report each condition recorded for the baseyear and what, if any other aspects of facility operation will be monitored.

Early warning of the need to consider a Baseline Adjustment may be given by

- regular monitoring of the utility bills and other measurement records, and
- regular tracking of the cumulative deviation of actual savings from the expected savings.

The facility owner/manager has an obligation to keep other parties informed about any planned or unplanned changes that may cause Baseline Adjustments. The notification should be as soon as possible after the change is detected so that information about the change can be collected promptly before circumstances and details are forgotten. Where future changes can be anticipated, details and impact of the change should be included in the M&V Plan.

When there is permanent change to a facility, the Baseline Model may be modified permanently to incorporate that change. Some changes in facility operations are only temporary, such as when there is a plant breakdown. The impact of such changes on Baseline Energy only applies for the period of the change.

When there is a separable physical change to the facility, such as the addition of a new building, the best approach is to use a submeter to isolate the energy attributable to the new building. The submetered energy can then simply be subtracted from the whole-facility utility meter.

The party responsible for determining and reporting savings usually has the knowledge, skills and experience to estimate the impact of the change and quantify the Baseline Adjustments. All parties should cooperate so that the issues can be resolved and agreed as soon as possible after the need for a Baseline Adjustment is identified.

What you should remember about Routine and Baseline Adjustments

- The quality, acceptability and correctness of reported savings depend on both the routine adjustments and the non-routine Baseline Adjustments.
- Routine Adjustments are defined by the M&V Option and are made for predictable changes in non-ECM conditions between the baseyear and the post-retrofit periods.
- Baseline Adjustments are made for unpredictable changes in non-ECM conditions between the baseyear and the post-retrofit periods.
- Baseline Adjustments are one of the most difficult M&V issues to manage and are a potential source of conflict if not managed properly.
- Concerns about Baseline Adjustments are centered around the uncertainty of what is going to change, when it is going to change and how the impact of the change will be assessed and agreed.
- Concerns can be managed by using the combined knowledge, skills and cooperation of all the parties.
- Be diligent about recording relevant baseyear conditions, tracking material changes, and resolving issues as quickly as possible after a material change is identified.
- The discipline and commitment in preparing and following an M&V Plan and in minimising errors could be wasted if Baseline Adjustments are not managed properly.
- There are benefits to all parties in minimising risks to reported savings from unexpected material changes.

CHAPTER 6: MANAGING DATA FOR BETTER M&V RESULTS

"Garbage in – Garbage out"

Background

Meters and instruments are used to measure and record

- pre-retrofit and post-retrofit energy data,
- data representing baseyear conditions, and
- other measurements required for various ECM types and technologies, such as runtime, temperature, humidity, flow, pressure, and derived measurements such as thermal energy.

Data for some baseyear conditions, such as occupancy, working hours, scheduled holidays, number of computers, and areas, are available from administrative systems and/or through publicly available free or paid-for information.

This Guide does not address details about the functioning, technology, availability or appropriateness of various meters or instruments typically used to measure and record data for M&V. **The Guide assumes that meters and instruments are available, they function as designed, they are calibrated and satisfy applicable standards, and skilled staff use best practices to record the conditions under which measurements are taken and to minimise any errors or missing data.**

Readers who require further information on measurements and instrumentation can obtain it from standard textbooks on the subject or from qualified practitioners. The following references have information directly related to measurement and instrumentation for M&V applications:

- IPMVP Volume 1, Chapter 5 and Appendix C for an overview on measurement issues
- ASHRAE Guideline 14-2002 Section 7 for guidelines on instrumentation and data management
- ASHRAE Guideline 14-2002 Annex A for details about the measurement of various physical characteristics of equipment used in energy subsystems.

Any statement of measured savings includes a degree of uncertainty whether it is explicitly stated or not. These uncertainties in savings are attributable to errors in assumptions, measurement, sampling and/or modelling. Guidelines on how to combine all these errors and derive overall savings uncertainty are presented in Chapter 8.

This Chapter discusses what should be done to minimise the contribution of measurement and data management errors to overall savings uncertainty. The Chapter assumes that the M&V Plan specifies the M&V Option (A, B, C, or D) and details required measurements.

The focus of this Chapter is on presenting practical issues about managing and using the data required for the savings determination calculations.

Energy and non-ECM data

Quantities of energy use in the savings equation can be "measured" by one or more of the following techniques:

- Utility invoices or meter readings
- Special meters isolating a retrofit or portion of a facility from the rest of the facility.
- Separate measurements of parameters used in computing energy use..
- Computer simulation calibrated to some actual performance data for the system or facility being modelled.
- Agreed assumptions or stipulations of ECM parameters that are well-known.

The measurement boundary of the savings determination, the responsibilities of the parties involved in the project implementation, and the significance of possible assumption errors will determine where assumptions can reasonably replace actual measurement.

For example, in an ECM involving the installation of more efficient lighting fixtures without changing lighting periods, savings may be determined by simply metering the lighting circuit power before and after the retrofit and stipulating the operating period.

Metering

Utility metering

Utility metering is provided by electricity, gas and water utilities to measure and record utility use and demand for their own operational purposes and for revenue billing. Utility meters are owned and maintained by the utility provider or accredited agents and must not be interfered with by anyone else. National standards govern the long-term accuracy and appropriateness of use of utility meters.

Normally one or more utility meters are used at the boundary of a facility to measure the utility inflows into the site. The meters are read periodically (monthly or quarterly) and, depending on the type of meter, are read by meter readers or remote data collection. The meter data is used for preparing periodic bills, which present sufficient data to support calculation of the payment.

Some utilities are delivered by tankers or containers, such as distillate and LP gas. The record of delivery and billed amounts reflect what, when and how much was delivered, which are not a specific measure of how much was consumed for any given measurement period. The consumption for a given period can be estimated by recording tank levels at the time of each delivery and/or extrapolating use from long-term averages. This type of estimation can be a significant source of error in calculated savings. Details of how this type of estimation is done have to be recorded for scrutiny by others

Major advantages of utility metering and billing are that they are:

- Invaluable sources of historical data with the best available accuracy
- Stable continuing sources of data
- No capital or O&M costs to the facility owner/manager and a relatively small cost (if any) to obtain the data from the utility, if it is available
- Measured and recorded by a utility provider, who is independent of the parties with interests in the savings determination outcomes.

The major disadvantages of utility metering are :

- They measure only combined inflows to the total facility and do not usually measure the supply to separate buildings or parts of the facility.
- Some facilities may have more than one supply point with a meter for each. This requires additional data management and can lead to errors in deriving time-coincident measurements for the overall site, such as for maximum monthly demand. The advantage is that the separate meters may be useful for M&V in isolating the energy supplied to parts of the facility.
- For a number of reasons the utility provider may not be able to retrieve and supply historical billing data. This has occurred in Australia when billing systems were upgraded or replaced and the new billing system was incompatible with the previous one. It is also an unintended result from competition in energy supply when the contracting utility is changed. The unavailability of data limits the selection of the baseyear period and may even cause a change from Option C to Option D.
- The billing periods (and meter reading period) for manually read meters are not usually on a calendar basis. The billing periods can vary irregularly from bill to bill and can start on any day in a month. Also, some billing practices use “Previous Reading Date” and “Last Reading Date” to delineate the billing period whereas others use the “Start Date” and “End Date” of the billing period. If care is not exercised, errors can be introduced by using incorrect calculations to determine the number of billing days from the dates presented in the bill.

The availability of historical and continuing billing data is the major reason why Option C was the first method used for M&V and continues to be a widely used Option. It is the most commonly used M&V method in Australia.

Submetering and retrofit isolation metering

Submeters are used to measure the energy supplied to parts of a building and/or to separate buildings in a facility complex. They are normally owned, maintained and read by facility staff manually or remotely by data collection systems. The required standard of accuracy for submeters is less than that for utility meters but the typically is adequate for M&V applications.

Submetered data is normally used for energy and cost accounting to separate parts of the facility and/or separate organisational cost centres. They are also used in a facility such as a shopping centre for tenant rebilling.

The major disadvantage of submetering is that it is often installed as a part of the ECM and therefore no pre-retrofit historical data is available to plan and design the best savings determination method.

Submeters can be used for Option A and B for retrofit isolation of the energy depending on the "boundary of measurement" and the interactions between the ECM and other parts of the energy infrastructure. Submeters would be installed permanently if continuous measurement was required in the post-retrofit period. However, if spot or short-term measurements are specified, temporary metering may be adequate.

Many difficulties encountered with retrofit isolation metering are caused by different end-uses being supplied through the same circuit wiring. The most common example of this is having light and power on the same distribution circuit. When this occurs spot or short-term measurements have to be taken at the terminals of the end-use equipment or appliance. This is a time-consuming and repetitive task when the energy retrofit is for large numbers of similar end-use devices, such as for a lighting retrofit.

It is common practice for energy retrofits, such as lighting efficiency ECMs, to use sampling to reduce the time, effort and cost of the retrofit project. This introduces sampling errors which have to be managed both in sampling design and conduct of the sampling. The theory and practices of sampling design to control sampling errors is well understood by measurement professionals. Sampling is used widely in many applications, such as the ABS Census.

It is expected that for new buildings the trend will continue of using separate distribution circuits (and maybe metering) for different end-uses. This would be of great benefit to M&V.

Traditional accumulation and demand meters

Consumption

Accumulation metering is the traditional form of metering used for measuring energy consumption. It measures a quantity and continually records cumulative consumption on a set of dials or digital display, which are read and recorded by the meter reader. Energy consumed between any two consecutive meter readings is calculated by subtracting the two readings and multiplying by a "meter factor". The meter readings and calculated consumption data are presented in the bills.

As explained previously, the start and end dates of the meter reads and the number of days between meter reads are not always regular or predictable. They depend on the meter reading schedule allocated to the meter reader. Care has to be taken to avoid unnecessary errors when performing calculations with accumulated meter data from different billing periods:

- The data has to be pro-rated so that there are a comparative number of days.
- For regression analysis, the start and end dates for the energy data have to be aligned with the start and end dates of the explanatory variables used in the regression analysis. This is a mathematical imperative for regression analysis. Energy accounting and specialised software tools used for M&V savings determination have the necessary in-built time-shifting and pro-rating capabilities. If a general software tool - such as Microsoft Excel - is used the time-shifting and pro-rating has to be done manually, which could introduce errors. The normal practice is to time-shift and pro-rate the data into calendar months.

Demand

Traditional maximum demand meters operate on similar principles but instead of accumulating consumption they measure and record the monthly maximum demand for the billing period. Potential errors associated with demand measurements are:

- If there is more than one supply point and monthly total maximum demand has to be derived from the separate demand meters, the maximum demands recorded by each of the separate meters cannot be added algebraically as the maximum demand for each supply point will most likely occur at a different time and possibly on a different day. This is not a problem if the savings determination is done for separate ECMs on separate meters. The easiest way of solving this problem is to remotely read smart meters (see below).
- The most common problem with demand measurements is that a spurious event, such as a short-term equipment malfunction, can cause an abnormally high spike in maximum demand. Unfortunately, a traditional demand meter will remember the abnormal spike as the monthly maximum demand. Such abnormal demand readings stand out when the monthly maximum demand is plotted against time. When conducting a regression analysis of demand data, the abnormal

demand readings may have to be discarded as outliers. If the outliers are discarded, the baseyear period for the regression analysis has to be extended so that there are still a minimum of twelve (12) valid data points.

Time-of-Use (TOU)

Traditional accumulation meters are used to measure time-of-use (TOU) consumption for periods such as Peak, Shoulder, and Off-Peak. This TOU split is useful if the ECM is designed to save energy costs by shifting energy consumption from Peak and/or Shoulder periods to the Off-Peak period, which has a lower price.

Traditional demand meters can be used to measure monthly TOU maximum demands but quite often only measure the non-TOU maximum demand.

TOU metering is used when the tariff for the meter has TOU prices to encourage end-users to shift consumption and reduce demand to TOU periods with lower prices. The extra TOU detail may or may not be useful for savings determination of a specific ECM. If one of the ECM benefits is load shifting, the TOU breakdown can be useful.

However, it is difficult to obtain statistically valid Baseline models for each of the TOU periods for a specific meter. Often it is possible to create separate Baseline models for a combined “Peak and Shoulder” period and for the Off-Peak. The only way to decide whether TOU Baseline models are statistically valid is to try the regression analysis for a selected TOU period and use the statistical measures to retain or discard the Baseline model.

The best approach to creating valid Baseline models is to keep the models as simple as possible. TOU data is available only because the utility wants to use a TOU tariff to calculate billing charges. They were not installed to make savings determination easier or to improve the accuracy of reported savings.

However, care must be taken when calculating costs savings from an ECM where TOU is applied. If the ECM mainly reduces consumption in Shoulder or Off-Peak times then the unit costs in those times should be applied in calculating savings. Often an ‘average’ unit price is used however this includes the more expensive Peak charge and will increase calculated savings above the actual.

Smart meters

A “smart meter” is an electricity meter with capabilities to continuously measure, compute and record, for extended periods, the values of a number of electricity demand parameters with a time resolution down to fractions of a second. The term is generally associated with electricity metering for contestable sites where the end-user has contracted with a licensed Retailer to supply electricity to a site from the National Electricity Market (NEM) or equivalent de-regulated market arrangements.

Under the NEM rules, smart meters must be used to measure end-use consumption for sites with consumption greater than an annual consumption set by the various State-based electricity regulators in accordance with the National Electricity Code and the enabling legislation. The smart meters for the NEM are programmed to record and store half-hourly demand, which is a requirement of the operation of the market.

Because smart meters provide half-hourly load profiles the information is very useful for monitoring and identifying unexpected or abnormal operations at the site. This information is useful when investigating incidents and changes that may require Baseline Adjustments. For example, if a building control system malfunction switched unnecessary equipment in the very early hours of the morning, this could be identified from the daily load profile. The half-hourly detail would be useful in estimating the Baseline Adjustment.

The half-hourly load profiles are also very useful in identifying spikes in demand and classifying them as outliers in the energy dataset for the baseyear period. Examination of the load profiles would be very helpful in estimating a replacement value for the outlier. The handling of outliers must be documented in the savings report.

When there are multiple supply points to a site, smart meter data can be used to accurately compute time-coincident total monthly maximum demand, as the half-hourly smart meter readings are time-tagged with a day and time stamp.

Electricity bills for contestable sites are calculated for a calendar period. They are an excellent source of monthly data as the billing periods have predictable monthly periods. The billing period for a contestable bill is stated with a “Start Date” and an “End Date”. The monthly data can be easily time-aligned with monthly data for explanatory variables.

Explanatory variables

Weather data

In general, weather is the most significant influence on energy behaviour, but not for all ECMs. The only way to determine if weather is a statistically valid influence is to use regression analysis and evaluate the statistical indicators.

Weather data is available from the Bureau of Meteorology (BOM) for many sites throughout Australia, including populated sites where there is most likely an energy retrofit project requiring M&V. Government published weather data is normally regarded as the most accurate and the most verifiable available.

The closest BOM weather reporting station to a site is usually considered to be the best available source of weather data for the site. The location difference between the site and the BOM weather station inherently introduces an error in the regression analysis but practical experience has shown that these errors are usually not significant.

Another source of weather data would be a weather station located on the site. The advantage is that geographical location errors are minimised. The disadvantage is that time, effort and cost would be required to purchase, install, operate and maintain; it would have to be regularly calibrated to ensure data accuracy. If it was decided to use a site-based weather station, it would be prudent to regularly validate the data by correlating it against BOM-supplied data.

The weather data normally used as explanatory variables are computed from daily average or high/low temperature data. Even though temperature can be used as an explanatory variable, it has been established by experience that it is best to use two weather severity variables: Cooling Degree Days (CDD) and Heating Degree Days (HDD).

A high temperature for a very short period during a day would require less cooling energy to maintain internal building comfort levels than if the same temperature continued for a longer period. In some cases temperature can be high but may not be high enough to require any cooling energy at all to maintain internal building comfort levels. The converse applies to low temperatures, the duration of the low temperatures and the heating energy required to maintain internal building comfort levels.

Weather Bureaus throughout the world have standardised on using 18.3^{0}C (65^{0}F) as a standard Balance Point above and below which CDDs and HDDs, respectively, are computed. For example, if the average temperature for a day was 20.3^{0}C (two degrees above the standard balance point) the CDDs and the HDDs for the day would be equal to two (2) CDDs and zero HDDs, respectively.

Research and experience have shown that using the standard Balance Point is not appropriate for modelling building energy. Each building reacts differently to external weather influences depending on construction materials, insulation, internal heating from occupants and equipment, and building control strategies, and therefore each building has its own best Balance Point. Further it has been established that it is best to allow the regression models for buildings to have separate Cooling Balance Points and Heating Balance Points.

Specialised M&V software tools use regression models with separate Cooling Balance Points and Heating Balance Points and have the capabilities to find the best Balance Points to optimise the statistical validity of the model. Software tools automatically calculate the CDDs and HDDs for the optimised Balance Points and perform the regression analysis of baseyear energy against CDDs and/or HDDs and/or other selected explanatory variables. The statistical indictors described in Chapter 4 indicate which explanatory variables should be used in the Baseline model and whether the overall Baseline model is statistically valid.

An understanding of the basic concepts and terms used to model weather influences on building energy are helpful in assessing and questioning the quality and credibility of Baseline models and reported savings. (Refer to Appendix 6 for an example of daily high and low temperature data and the equivalent monthly and annual CDDs.)

Other Potential Explanatory Variables

Other potential explanatory variables are non-ECM factors such as occupancy, operating hours, operating schedules, and production throughput.

These factors have been described and discussed in previous Chapters. Data for these factors are usually available from administrative and operational records for the facility.

Measurement issues which influence the choice of which non-ECM factors should be tested for statistical significance depend on:

- The specific facility conditions and ECM.
- The availability and quality of historical data for the baseyear period of the Baseline model.
- The continuing availability and quality of this data during the post-retrofit period.
- The timely availability of the data during the savings determination processes.
- The data should be available for periods comparable to billing periods for energy data or for periods that can be computed to be comparable to billing periods. For example, if calendar billing periods are used for energy data, data for explanatory variables should be daily, monthly, or approximate monthly periods. It would not be acceptable for this example to have annual values of the explanatory variable. It would not be advisable to have quarterly data that has to be time-shifted and prorated to calendar monthly periods.
- There is a statistical validity requirement that the ratio of the highest to lowest data values for the baseyear period should be at least two to one (2:1).
- There is a further statistical requirement that the explanatory variable should be independent of each other. The specialised M&V software tools have the capability to indicate which explanatory variable fail this test and therefore should be excluded.

What you should remember about Managing Data

- Meters and instrumentation required for M&V are not special, but should be calibrated and used correctly.
- There are inherent measurement errors that have to be managed and care has to be taken in recording the conditions under which data was obtained.
- Care has to be taken not to introduce unnecessary errors though misrecording or losing data.
- There are advantages in using utility meters as they have historical data.
- Care has to be taken in using billed utility data as the detailed billed components may introduce unnecessary complexities into M&V processes.
- Sub-metering can be very useful to separate out the energy behaviours of different parts of a facility.
- It is best to use weather data recorded by the Bureau of Meteorology but you can use site-specific weather stations as long as you are committed to pay the money to keep it maintained and calibrated.
- You should be diligent about collecting, recording and safely storing your data on non-ECM conditions.

CHAPTER 7: BALANCING M&V COSTS AND BENEFITS

"Save your pennies – you will make your pounds"

Background

The objective of M&V planning is to design the M&V process to incur no more cost than needed to provide adequate certainty and verifiability in the reported savings, consistent with the overall budget for the energy savings project. This Chapter discusses:

- The need to balance the requirement to minimise savings uncertainties and the M&V costs that can be justified for the project.
- The factors that influence M&V costs
- The factors that contribute to overall savings uncertainty

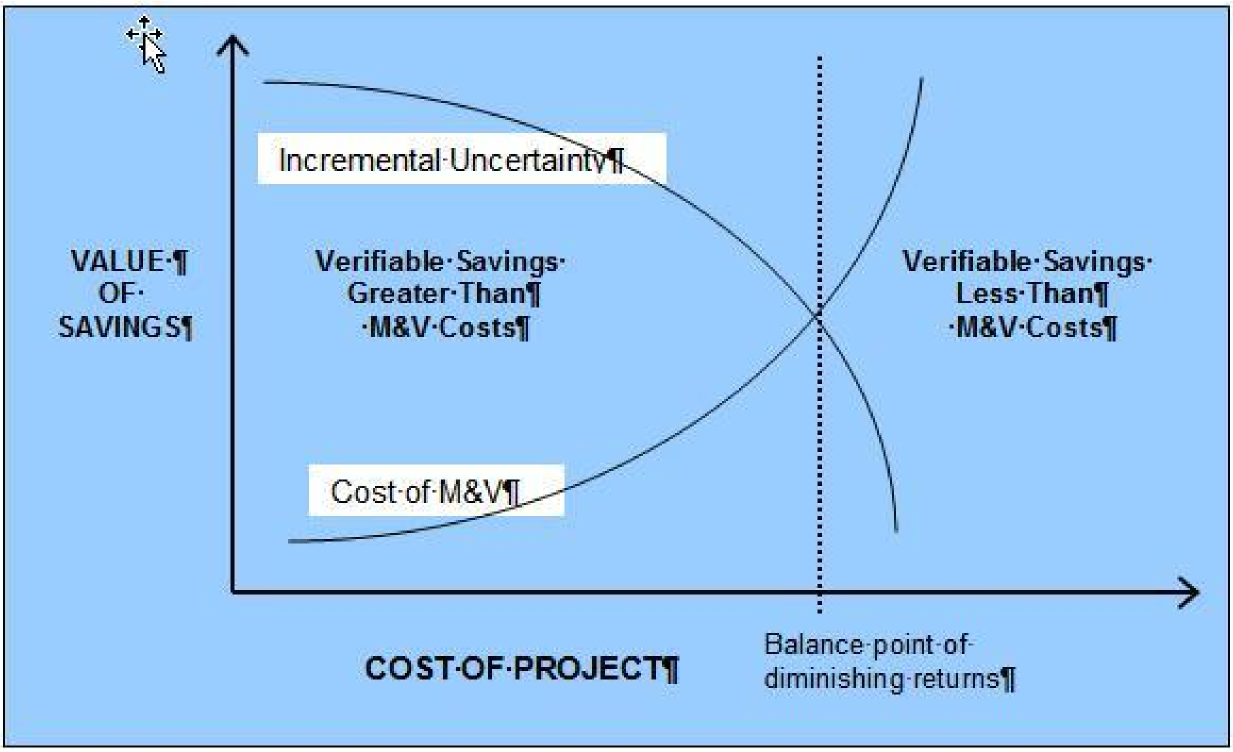
The information in this Chapter is an adaptation of guidance provided in Chapters 3 and 4 and Appendix B of the IPMVP 2001 (March 2002) Volume 1 and FEMP M&V Guidelines 2002 Section 1 Chapter 5.

Balancing uncertainty and cost

The levels of reported savings depend primarily on the design, installation, commissioning and savings performance of the ECMs. It is not the role or responsibility of the M&V processes to explain why the savings are greater or less than the expected (promised or guaranteed) savings or why the savings are increasing or decreasing over time. However, experience has shown that energy savings projects with properly planned and managed M&V have higher levels of savings, greater persistence and less variability of savings over time.

The time, effort and cost expended on the proper planning, design and implementation of M&V activities influence the quality and credibility of the reported savings. The acceptable level of uncertainty required in a savings calculation is a

Figure 7.1 Trade-off between M&V cost and savings uncertainty



function of the value of expected savings and the cost-effectiveness of decreasing uncertainty through additional time, effort and cost. The estimated savings for a specific project places limits on the expenditure that can be justified for M&V. Further benefits of activities to reduce uncertainty may be improved feedback to facility operations, improved reporting and identification of additional ECMs. These additional benefits may help justify additional M&V costs.

The planning and design of site-specific M&V should consider the accuracy required for various components in the savings calculation and their contribution to overall savings accuracy and confidence level. Both quantitative and qualitative uncertainty factors have to be considered when evaluating M&V cost options for each project.

When planning an M&V process, consideration should be given to the predictability, measurability and likely impact of potential factors such as weather, occupancy, etc. The effort undertaken in determining savings should focus on managing the uncertainties in the determination process. ECMs with which the facility staff are familiar may require less effort than other uncommon ECMs.

For a given savings determination model at a specific site, there will be an optimal savings determination plan. Identifying the best balanced choice for this Plan includes iterative consideration of the sensitivity of the savings uncertainty for each variable in the savings calculation, estimating the cost of reducing the uncertainty, and selecting a criteria for valuing reduced uncertainty.

Finding the best balance between uncertainty and cost is simply a question of risk management. **Figure 7.1 illustrates the balance point of diminishing returns when additional M&V cost is used to reduce uncertainty (Refer to Kumar V).** The amount of M&V may have to be varied over time depending on the level of realised saving, and the persistence and variability of the savings.

Factors affecting M&V costs

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

- M&V Option
- Number of ECMs, their type, complexity and amount of interaction
- For Options A, B and D, the number of energy flows across the “boundary of measurement” around the ECM.
- Level of detail and effort associated with establishing baseyear conditions
- Amount and complexity of measurement equipment
- Sample sizes used for metering representative equipment
- Amount of engineering required to establish stipulations used in Option A or the calibrated simulations for Option D
- Number and complexity of independent variables in the Baseline models
- Duration of metering and reporting activities
- Accuracy requirements
- Savings reporting requirements
- Process of reviewing or verifying reported savings
- Experience and professional qualifications of the people conducting the savings determination

Table 7.1 Ranking ECM complexity

Rank	ECM Performance and Operating Characteristics	Load	Hours
1	Constant load, constant operating hours	constant	constant
2	Constant load, variable operating hours with a fixed pattern	constant	variable
3	Constant load, variable operating hours without a fixed pattern (e.g. weather)	constant	variable
4	Variable load, constant operating hours	variable	constant
5	Variable load, variable operating hours with a fixed pattern	variable	variable
6	Variable load, variable operating hours without a fixed pattern (e.g. weather-dependent)	variable	variable

The key governing cost factors for each M&V Option are as follows:

- Option A – Number of measurement points, complexity of stipulation, frequency of post-retrofit inspections
- Option B - Number of measurement points and the periodicity and duration of the measurements
- 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 simulation expert in achieving calibration

Option A normally has the lowest cost because stipulation reduces the number of measurement points, providing the effort in establishing the stipulation is reasonable and the required number of post-retrofit inspections are not excessive.

The cost of acquiring, using and maintaining new measurement equipment often required for Options A or B may make Option C a less costly endeavour especially if the savings have to be determined for long periods. However, the costs of extra meters for Options A or B may be shared with other objectives e.g., energy cost allocation.

When multiple ECMs are installed at one site, it may be less costly to use the whole building methods of Options C or D than to isolate and measure multiple ECMs with Options A or B.

Though development and calibration of an Option D simulation model is often a time consuming processes, it may have other uses such as designing the ECMs themselves or designing new facilities.

Where a contractor is responsible for only certain aspects of project performance, other aspects may not have to be measured for contractual purposes, though the owner may still wish to measure them for its own sake. In this situation, the costs of measurement may be shared between owner and contractor.

Table 7.1 ranks ECM complexity according to performance and operating characteristics (i.e. constant or variable). Higher ECM complexity may justify more rigorous and costly M&V procedures especially if the associated savings are high yet uncertain. This Table is adapted from Table 5.2 in FEMP M&V Guidelines 2002 Section 1 Chapter 5.

Table 7.2 presents considerations that affect the level of effort and cost required to complete the project M&V. The summary is useful for assessing if the estimated M&V cost is justified from the level of effort described. This Table is reproduced from Table 5.2 in FEMP M&V Guidelines 2002 Section 1 Chapter 5.

Cost of determining savings

It is difficult to generalise about costs for the different Options since each project will have its own unique set of constraints.

Both the IPMVP 1997 and IPMVP 2001 (March 2002) Volume 1 quote the rule of thumb that typically, it would be expected that the average annual savings determination costs do not exceed more than about 10% of the average annual savings being assessed. They are often much less.

Table 7.2 M&V components affecting level of effort and costs

Component	Considerations
Verification of baseyear and post-installation conditions	Level of detail required
Metering sample	Size of sample
Metering duration	Time period required to characterize performance or operation; contract term
Metering points	Number of data points required; number and complexity of dependent and independent variables
Metering equipment	Availability of existing collection systems (i.e., ECMS)
Metering accuracy	Equipment accuracy; confidence and precision levels specified for energy savings analysis

Often the M&V costs can be shared with other objectives such as operational feedback, tenant re-billing, energy accounting and reporting.

Table 7.3 presents the information in the referenced Tables in the FEMP M&V Guidelines Version 2.2 and in IPMVP 1997. The table in IPMVP 1997 was deleted from IPMVP 2001.

The M&V Costs shown in Figure 7.2 is from a presentation at the U.S. Energy 2001 conference (Refer Sharp, T). It gives an indication of the range of M&V costs as a “percentage of savings” across a sample of 30 projects.

The available information on typical M&V costs is very difficult to use as guidance for a specific project. From the information presented the M&V costs may be in the range of 3% to 5% of the expected savings.

It is a commercial and risk management decision about the amount of money that is allocated for M&V and the expected quality and credibility of the reported savings.

Table 7.3 M&V Options and typical costs

M&V option	How savings are calculated	Cost (as percent of construction costs) (FEMP M&V Guidelines Section II Chapter 5 Table 5.1)	Cost (as percentage of ECM energy savings. (IPMVP 1997 Section 3.10 Table 3)
Option A	Engineering calculations using spot or short-term measurements, computer simulations, and/or historical data	Depends on number of measurement points. Estimated cost range: 1%—5%	Estimated range is 1%-3%. Depends on number of points measured.
Option B	Engineering calculations using metered data	Depends on number and type of systems measured and the term of analysis/metering. Estimated cost range: 3—10%	Estimated range is 3%-15%. Depends on number of points and term of metering.
Option C	Analysis of utility meter data using techniques from simple billing comparison to multivariate regression analysis	Depends on number and complexity of parameters in billing analysis. Estimated cost range: 1%—10%	Estimated range is 1%-10%. Depends on complexity of billing analysis.
Option D	Calibrated energy simulation/modelling calibrated with utility billing data and/or end-use metering	Depends on number and complexity of systems evaluated. Estimated cost range: 3%—10%	Estimated range is 3%-10%. Depends on number and complexity of systems modelled.

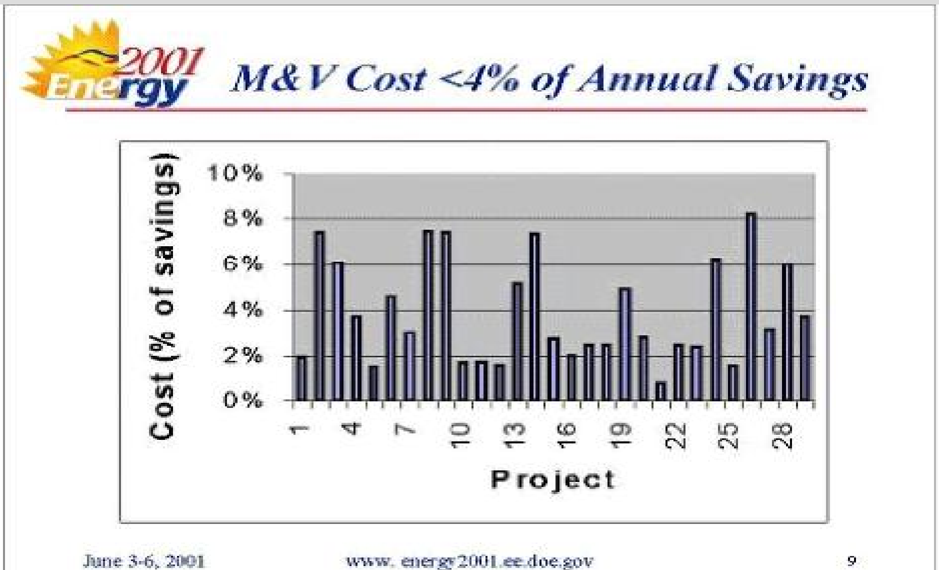


Figure 8.2 Typical M&V cost as a percentage of savings

Savings uncertainty

Factors affecting savings uncedrtainty

Many factors affect performance of equipment and achievement of savings. Depending upon the scope of the savings determination and its measurement boundary, the range of parameters that contribute to overall savings uncertainties can be very focused around the specific ECMs or they can be related to the whole facility.

- Parameters that are predictable and measurable can be used for routine adjustments. These adjustments reduce the variability or provide a greater degree of certainty in reported savings.
- Unpredictable parameters within the boundaries of the savings determination may require future non-routine Baseline Adjustments.
- Unmeasured parameters give rise to savings fluctuations for which no adjustment can be estimated and can only be guessed.

In most cases, improving accuracy by any of the above increases M&V costs. Such extra cost should be justified by the value of the improved information.

Overall savings uncertainty

The savings determination process itself introduces uncertainties through the following types of errors:

- Measurement and Instrumentation Errors: The magnitude of instrumentation errors is given by manufacturer's specifications. They are typically small and are not a major source of error. However, errors can be introduced through the improper use of the instruments or if the required calibrations are not maintained.
- Modelling Errors: Modelling errors are inherent errors in creating and using the Baseline models or other computational models. Bias error can occur if the specification of the models is not correct through factors such as omitting important terms from the model, assigning incorrect values for "known" factors, and extrapolating the model results outside their range of validity.
- Sampling Errors: These result from the fact that measurements were taken from a sample of items rather than from the entire set of items under study.
- Planned and Unplanned Assumptions: These errors cover all the unquantifiable errors associated with stipulations, and with other assumptions necessary for measurement and savings determination.

There are practical statistical techniques for combining the components of uncertainty and deriving an overall uncertainty for the calculated savings. These techniques are beyond the scope of this Guide. Readers requiring further information on this should begin by reading the IPMVP Volume 1 Appendix B.

Ways of improving savings accuracy

There are two general ways of improving accuracy of savings estimates:

- By reducing biases, by using better information or by using measured values instead of stipulated values
- By reducing random errors, either by increasing sample sizes, using a more efficient sample design or applying better measurement techniques.

Some specific ways of improving accuracy of savings estimate are:

- For buildings, one or more full years of energy use and weather data should be used to construct regression models. Shorter periods introduce more uncertainty through not having data on all operating modes and not covering all seasonal influences equally.
- Varying the required length of metering depending on the type of ECM. If energy use is fairly constant, the period required to determine annual savings can be short as short-term measurements can be extrapolated. If there is daily and seasonal variation, a much longer metering period or continuous metering may be required.

Quantifiable and qualitative uncertainty

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.

Quantified uncertainty should be expressed in a statistically meaningful way, by declaring both accuracy and confidence level. A statistical precision statement without a confidence level is meaningless. For example, a savings report should include a statement such as "The quantifiable savings error is estimated at +20% with a 90% confidence level".

Determining savings means estimating a difference in level rather than measuring the level of consumption level itself. In general, calculating a difference with a given relative precision level requires greater absolute precision of the components of the savings determination calculation.

What you should remember about balancing M&V costs and benefits

- M&V plans should be designed to incur no more cost than is needed to provide adequate certainty and verifiability in reported savings, consistent with the overall project budget.
- The estimated quantity of savings for a specific project places limits on the expenditure that can be justified for M&V.
- The acceptable level of uncertainty required in a savings calculation is a function of the value of expected savings and the cost-effectiveness of decreasing uncertainty through additional time, effort and cost.
- Overall savings uncertainty has to take into account measurement errors, modelling errors, sampling errors and errors from assumptions that may not continue to be appropriate.
- Improving accuracy usually increases M&V costs.
- Finding the best balance between uncertainty and cost is simply a question of risk management.
- Higher ECM complexity may justify more rigorous and costly M&V procedures, especially if associated savings and savings uncertainty are high.
- The general rule of thumb is that typically the average annual savings determination costs should not exceed more than about 10% of the average annual savings being assessed and are often in the range of 3% to 5%.

CHAPTER 8: COST AVOIDANCE

“Show me the money”

Background

As described in Chapter 1, M&V Protocols and Guidelines were developed to remove barriers to capital investments in energy efficiency projects by giving financiers, customers and contractors assurances about the quality and credibility of the calculated savings, thus assisting them with the evaluation and management of financial risks.

The information provided in Chapters 2 to 7 refers only to best practices for determining energy savings, identified as KWh of electricity, GJ of gas, kL of water etc.

This Chapter focuses on the issues involved in calculating the financial equivalents of these energy savings, which are the most important sources of cash-inflows to repay the financial investment in the project.

The fundamental question is:

“What prices should be used for the conversion of energy savings to energy cost savings and how should any price risks be managed?”

This Chapter introduces the concept of Cost Avoidance which has not been commonly used in Australia to date. The term is useful in differentiating the accounting interpretation of energy cost savings and the interpretation most applicable to energy savings projects.

A major objective of many energy savings projects is the reduction or substitution of electricity use and/or demand. The discussion in this Chapter is primarily based on the processes and issues for calculating electricity cost savings. The same general issues apply to calculating all other forms of utility cost savings.

The IPMVP does not give any detailed guidance on how best to convert the measured and verified energy savings to energy cost savings. The IPMVP focuses on the measurement and verification of energy savings only and considers that their conversion to a monetary value is a contractual and financial matter. Energy Price issues are mentioned briefly in Section 4.5 of IPMVP 2001 (March 2002) and an example of energy cost savings calculations are presented in Appendix A (Option D).

The information in this Chapter is based on general industry practices used in the U.S. and Australia, on M&V experiences in Australia, guidance provided in FEMP M&V Guidelines 2002 Section 1, Chapter 4 Section 4.7., and in literature (Refer to Hansen, S.J, Appendix A).

Electricity prices

With the introduction of competition in the deregulated electricity markets, there are two mechanisms for setting prices.

1. End-use customers who have sites not eligible to be supplied from the deregulated market or who have elected not to buy from the deregulated market, have to accept the regulated prices set in accordance with the applicable State laws and regulations. These customers generally referred to as “franchise customers” and they pay “franchise prices”.
2. End-use customers who have elected to purchase supply from the deregulated market, through licensed Retailers, have to accept prices determined by the market influences that exist at the time of the purchase. These customers are referred to generally as “contestable customers” who are supplied under “contestable contracts” and pay “contestable prices”.

Both types of prices have price variations over time but the price risks faced by the two types of customers are substantially different.

- For regulated prices, the price changes are fairly predictable. In general, there is an annual price increase, usually applying as at the 1 July each year, related directly or indirectly to annual CPI increases.
- For contestable prices, the price changes are less predictable over the long-term but more predictable during the term of a contestable contract. Prices are usually fixed for each 12 month period within the contract term with pre-defined increases or decreases for each subsequent 12 months. By the expiry date of an existing contract, a customer must have arranged a new contestable contract. The customer has choice in selecting the Retailer for the new contract period but has practically no influence over the prices accepted from the new Retailer. The new

prices are determined by a mixture of market influences prevailing at the time of the purchase. New prices must be accepted by the customer irrespective of whether they are higher or lower than the prices in the previous contestable contract.

Both regulated and contestable customers have no real control over the time-variation in prices and must manage the inherent price risks. These price variations create variable energy cost savings even if the quantity of energy savings remains constant.

For example, consider an energy savings project with guaranteed annual energy savings of 100,000 kWh and calculated annual energy savings remaining constant at 100,000 kWh for the first two years of the performance period:

- If the prices for the first year and second year were 10 cents and 11 cents per kWh, respectively, the annual energy cost savings would be $10,000 and $11,000 for the first year and second year, respectively.
- If the prices for the first year and second year were 10 cents and 9 cents per kWh, respectively, the annual energy cost savings would be $10,000 and $9,000 for the first year and second year, respectively.

In this example, the guaranteed annual energy savings were achieved. However, the annual energy cost savings may or may not be acceptable to the financiers depending on the assumptions about energy prices and future price movements made in the financial models used to justify the project investment. If the financial model was based on a constant price of 10 cents per kWh, the annual cash inflow for the guaranteed annual energy savings would be $10,000. Note that:

- The calculated annual energy cost savings for the first year, using the prevailing price for the first year, was on target because the price for the first year was the same as the assumed price.
- If the price for the second year was 11 cents per kWh, the calculated annual energy cost savings for the second year would exceed the expected annual cash inflow by $1,000 because the second year price was higher than the expected price.
- If the price for the second year was 9 cents per kWh, the calculated annual energy cost savings for the second year would be less than the expected annual cash inflow by $1,000 because the second year price was lower than the assumed price.

This simple example shows that price variations from the assumed price in financial models can affect whether the project is judged to be financially successful or unsuccessful, even when the expected annual energy savings are achieved. Because customers and contractors have no control over price variations, the success or failure of an energy savings project should be judged on the energy savings, or on cost savings calculated with prices that do not include unexpected price variations.

Cost avoidance

<u>The Problem</u>

The success or failure of an energy savings project should be judged on the reconciliation between the expected and achieved energy savings. If the energy savings are equal to or higher than expected the project is a success. However, financiers and accountants make judgements about project success or failure based on achieved cost savings relative to expected cost savings. The usual management accounting criteria for deciding cost savings is whether current spending is less than previously spent or expected to be spent. The following simple example highlights the management accounting view of the success or failure in reducing energy costs.

An energy manager has been asked to take action to reduce electricity costs, and is successful in reducing previous consumption Q_1 (kWh) to a lower consumption of Q_2 (kWh). However, allowance was not made for any price changes between the price paid before the energy reduction P_1 (cents/kWh) and after the energy reduction P_2 (cents/kWh). The management accounting view is that the energy manager would be successful if the current cost of $\$(P_2 \times Q_2)$ is less than the previous cost $\$(P_1 \times Q_1)$. The management accounting view does not differentiate between the following two situations:

- <u>Case 1</u>: The energy manager is successful in reducing consumption ($Q_2 < Q_1$) but the current billed cost is higher than the previous bill because there was a price increase ($P_2 > P_1$)
- <u>Case 2</u>: The energy manager is not successful in reducing consumption ($Q_2 > Q_1$) but the cost in the current electricity bill is lower than for the previous bill because there was a price decrease ($P_2 < P_1$)

The management accounting view of cost savings cannot differentiate between Case 1 and Case 2.

The Solution

The Cost Avoidance view of cost savings differentiates between the above two cases by calculating an "avoided cost", which is the difference between the cost if the energy reduction had not been made and the current cost after the successful energy reduction. Cost Avoidance is based on the same concept as "avoided energy" described in Chapter 2. "Avoided energy" is the difference between the estimated Baseline Energy under post-retrofit conditions and the Actual Energy measured in the post-retrofit.

In the example described above the "avoided cost" is normally calculated by using the current price P_2 to convert energy savings to money savings by the formula

Cost Avoidance = $\$(P_2 \times (Q_1 - Q_2))$.

In the general case, the "avoided cost" is the "avoided energy" multiplied by a price.

- Using "avoided energy" ensures that the energy savings are calculated using energy quantities that have been determined under the same conditions.

  Using a common price ensures that any cost increases or reductions caused by price changes are not included. Price changes should be excluded by using a current price (P_2) as the common price to convert the billed energy before (Q_1) and after (Q_2) into costs under the same pricing conditions.

In the energy manager example, it would not be correct to simply subtract the Baseyear energy (Q_1) and the Post-Retrofit Energy (Q_2) as some of the energy reduction may have been caused by factors outside the energy manager's control, such as an increase or decrease in the number of occupants. The Baseline Energy should be used for Q1. The energy manager has no real control over price changes and therefore cost variations due to price changes should be excluded.

In Figure 8.1 the area between the Baseline Energy (shown in blue) and the Post-Retrofit Energy (shown in black)measured during the Performance Period would represent the "avoided cost" if both the the difference between the Baseline Energy and the Post-Retrofit Energy were multiplied by a common price, such as the current price in the post-retrofit period.

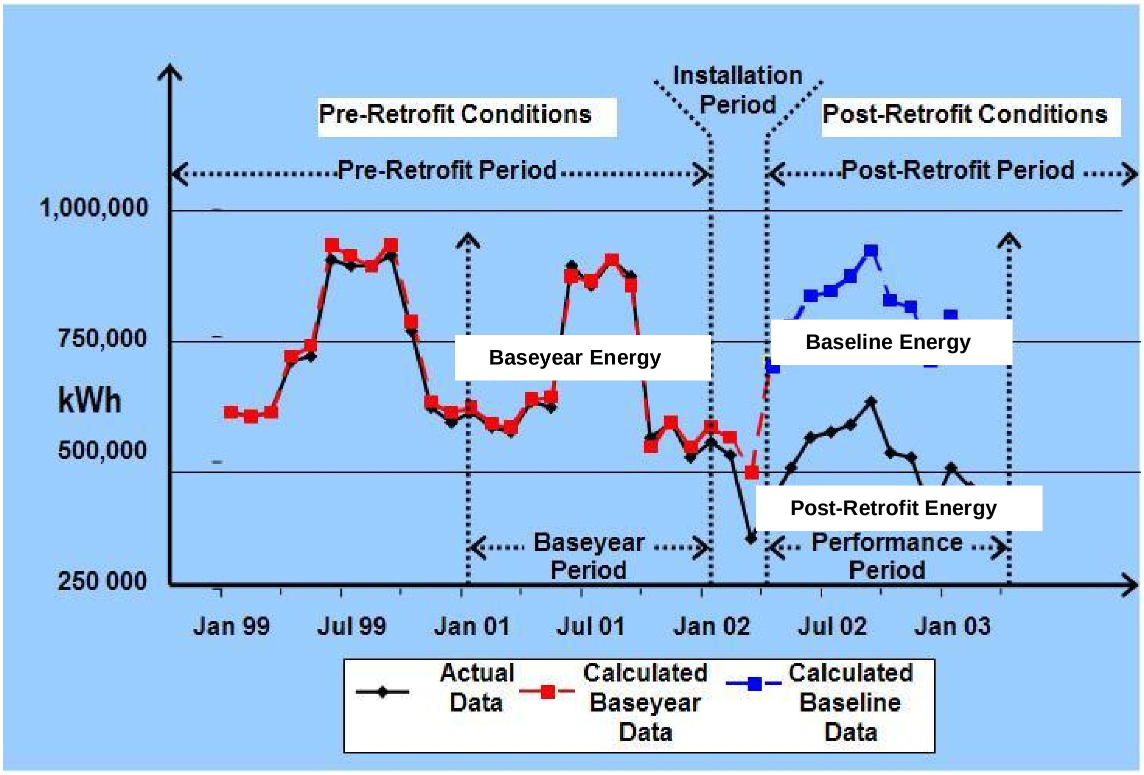


Figure 8.1 Cost Avoidance is the Avoided Energy multiplied by a Price

Selecting the price

Selecting the price used to calculate cost avoidance dollars is mainly a project financial evaluation and contracting issue but the decision is also influenced by the M&V method, the practicality of the Baseline modelling and the price structure to be used for cost calculations. Details on price and cost calculations should be included in the M&V Plan. The M&V savings report should include the basis on which dollar savings were calculated and the price used to convert energy savings to energy savings dollars.

Standard use of cost avoidance

The standard definition of "cost avoidance" uses the current price as the common price to calculate "cost avoidance" dollars. This definition can be used for in-house energy savings projects or for projects where the energy savings objective is simply to reduce billed costs. In these situations, the practical choice is to use the current price. A bill cost reconciliation statement would report the difference between the billed cost $\$C_2$ for the current reporting period and the total billed cost $\$C_1$ that would have been billed if energy reduction actions had not been taken. The cost avoidance calculation in this case is

Cost Avoidance = $(\$C_1 - \$C_2) = P_2 \times (Q_1 - Q_2)$

where

- P_2 is the energy price for the current reporting period
- Q_1 is billed energy for the previous period adjusted for differences in conditions between the current period and the previous period
- Q_2 is billed energy for the current period
- $(Q_1 - Q_2)$ is the "avoided energy" under the current period conditions

Cost Avoidance for EPCs

For energy performance contracts, it is normal practice to guarantee only the annual energy savings and to use the energy savings reconciliation as the measure of success or failure of the savings performance of the EPC.

However, the ESCO has to calculate the annual dollar value of energy savings as this information is used in financial modelling for project investment and debt repayment decisions. The price, and assumptions made about the price used by the ESCO and in the financial modelling should be the same and should be documented fully in the contract. M&V has an influence on the selection of the price and method used to calculate annual cost avoidance dollars.

There are a number of issues about the selection of the price, calculation method and assumptions.

- Normal practice for EPCs is to use a stipulated price as this totally removes price variation risk from the calculated cost avoidance dollars. The stipulated energy price is normally the price in the baseyear period (also used to estimate the cost savings) but it may be just an agreed price. This has the advantage that reconciliation of the cost avoidance dollars between expected and achieved is directly equivalent to the energy savings reconciliation. Consequently, the financial evaluation of the success or failure of the EPC should always be aligned with the engineering evaluation. However, it has the disadvantage that dollar savings calculated with the stipulated price cannot be directly compared to actual billed costs throughout the performance period. This may be a source of concern for management accounting staff not familiar with the cost avoidance concept.
- If a stipulated price is used, a decision has to be made about how it is determined. Common practice is that stipulated prices are based on the prices prevailing at the time the ESCO estimates the guaranteed annual energy savings and calculates the financial equivalent of the guaranteed energy savings. This has to be done before the EPC contract is signed, therefore the baseyear prices or prices prevailing when the ECM savings were calculated can be used. Note that in some cases, because of delays in final negotiation of the financial and contractual details, the baseyear period may not be aligned with the period when the guaranteed energy savings were estimated.
- If it is decided not to use a stipulated price, the only criterion for selecting price is that parties agree on the price, calculation method and assumptions. In this case all details should be fully documented so they can be used by those responsible for calculating dollar savings. There would be advantages in using the prevailing current price for each savings reporting period as this would make it easier for management accounting staff to compare cost avoidance dollar savings against actual billed charges. Because the savings reporting periods are

not necessarily aligned when price changes become effective, the parties have to agree on how the price is selected.

- When it is possible, it is best to use actual energy price tariffs from utility bills. However, it may not always be possible to do this. Most energy savings projects are implemented on sites that are on time-of-use (TOU) energy tariffs with separate prices for Peak, Shoulder, and Off-Peak energy consumptions. Experience with Baseline modelling has shown that it is very difficult to create separate statistically valid Baseline models for the TOU periods. Hence, Baseline Energy and "avoided energy" for the separate TOU periods cannot be estimated and TOU prices cannot be used directly to calculate separate TOU cost avoidance dollars. This may be a source of concern for management accounting staff who are not involved in the Baseline modelling decisions. There are a number of solutions to this common problem but the details are beyond the scope of this Guide. If further details are required the questions should be referred to M&V specialists.
- The other aspect that restricts the use of actual energy tariffs is the complexity of the tariffs, especially for contestable sites. Contestable price tariffs have separate prices for time-of-use (TOU) energy, TOU demand, other network charges, market management charges, metering services, and miscellaneous charges. In practice, "effective" prices may have to be computed for groups of the component charges. Details of how to reduce energy tariff complexities depend on the specific situation. Changes to actual energy tariffs in the bills may be a source of concern for management accounting staff not involved in the pricing simplification decisions. Details about creating "effective" tariffs for specific project situations are beyond the scope of this Guide. If further details are required the questions should be referred to tariff specialists.

What you should remember about Cost Avoidance

- The success or failure of an energy savings project should be judged on the achieved energy savings relative to expected energy savings.
- Financiers and accountants make judgements about success or failure of projects based on achieved cost savings relative to expected cost savings.
- The fundamental M&V financial question is what prices should be used for the conversion of energy savings to energy cost savings and how should any price risks be managed?.
- Both regulated and contestable customers have no real control over time-variation in prices and must manage the unavoidable price risks.
- Price variations over time create variable energy cost savings even if the quantity of energy savings remains constant.
- The management accounting view of energy cost savings does not differentiate cost variations caused by price and those caused by energy consumption.
- The Cost Avoidance view excludes cost variations caused by price by using a common price and therefore includes only cost variations due to energy consumption. Cost Avoidance is "avoided energy" multiplied by a selected price.
- The standard definition of "cost avoidance" uses the "current period" price to calculate "cost avoidance" dollars from the "current period" avoided energy
- It is best to use actual energy price tariffs from utility bills to calculate cost avoidance dollars, but it may not always be possible to do this.
- For EPCs, it is normal practice to guarantee only the annual energy savings and to calculate cost avoidance dollars using an agreed stipulated price to remove price variation risk from the reported energy cost savings.

CHAPTER 9: M&V FOR EPC PROJECTS

"Closing deals is so much trash – if you my friend, don't get no cash"

Background

AEPCA has a set of standard contract documents (*Standard Energy Performance Contract (EPC),* the *Standard Detailed Facility Study Agreement (DFSA),* and the *Best Practice Guide to Energy Performance Contracting (BPG-EPC)*) which are being used widely by parties to Energy Performance Contracting (EPC) arrangements. These documents are available on the AEPCA web site at http://www.aepca.asn.au.

Measurement and verification (M&V) is an important and integral part of an EPC project. The AEPCA standard contract documents include the necessary M&V obligations to determine energy savings in EPC arrangements. The BPG-EPC provides guidance on how to satisfy the M&V obligations in the EPC and DFSA documents. This Guide is a companion document to the BPG-EPC providing additional conceptual and operational details applicable to M&V for EPCs.

The IPMVP is used as the main source and reference for M&V guidance presented in the BPG-EPC and brief reference is made to the draft release of ASHRAE Guideline 14P. Since the BPG-EPC was produced in early 2001, a major revision of the IPMVP (in March 2002) and the final version of ASHRAE Guideline 14-2002 have been released. This latest version of the IPMVP has introduced some new terms and definitions that are adopted in this new Guide. This new Guide also introduces the concept of "Cost Avoidance" which is not used in the BPG-EPC.

The major purpose of this Chapter is to provide users of the AEPCA standard documents and the BPG-EPC advice on how best to use this new Guide to further their understanding of their M&V obligations and to improve how they plan and implement their M&V activities. In particular, this Chapter explains the difference in terms and definitions between the BPG-EPC and this new Guide.

M&V role in energy performance contracting

Energy Performance Contracting is when an energy service company (ESCO) is engaged to improve the energy efficiency of a facility, with guaranteed energy savings paying for the capital investment required to implement improvements.

Under a performance contract for energy saving, the ESCO examines a facility, evaluates the level of energy savings that could be achieved, and then offers to implement the project and guarantee those savings over an agreed term.

The ESCO is usually obligated to repay savings shortfalls, or implement additional work, over the life of the contract. At the end of the contract period the full benefits of cost savings revert to the facility owner.

Payments to the ESCO are contingent, to varying degrees, upon the level of energy savings achieved; and since outcomes are guaranteed by the ESCO, technical and financial risks are shifted from the Customer to the ESCO.

Once the ECMs are commissioned, the ESCO continues to measure or monitor energy use and costs of the project for the contract term. Actual energy costs are compared with baseline costs to determine total savings. Without adequate M&V, there is no basis for determining the amount of energy saved.

Typical contract terms are between four and 10 years - a relatively long period, but necessary to be able to structure the contract so the guaranteed savings cover the capital repayment and all ongoing costs to ensure a positive cash flow to the Customer.

M&V in the BPG-EPC

The primary aim of the BPG-EPC is to provide guidance to potential customers on:

- a process to procure an EPC suitable for all public authorities as well as private businesses, and
- the interpretation and implications of key clauses in the *Standard Energy Performance Contract* and *Standard Detailed Facility Study Agreement*.

Chapters 1 and 2 provide an overview of EPC and sets out the EPC contracting process recommended by the AEPCA. It shows how M&V processes should be conducted in parallel with the main EPC processes. Advice is provided that Customers may require assistance on M&V issues, especially if it is the first time they are involved in an EPC, as M&V issues are one of the most difficult EPC issues to manage.

Chapter 3 is the commentary on the *Standard Detailed Facility Study Agreement*. Advice is given that the M&V procedures need to be identified so that savings can be demonstrated over the life of the EPC. Details are provided of the results and outcomes to be documented and provided as part of the obligations of DFS Clause 3.1. The major clauses that refer to M&V are:

- Clause 3.1 (b) - *The energy consumption and demand profile and space conditions of the facilities on the premises*. The information is required to establish the baseline energy performance data of the premises. In this new "BPG-M&V" the term "baseline energy performance" is referred to as the "baseyear energy performance"
- Clause 3.1 (k) – *An MVP (M&V Plan) which is acceptable to both parties for monitoring, verifying and guaranteeing savings from the implementation of ECMs, based on the IPMVP.* The guide states that a comprehensive action plan is required of how the ESCO will demonstrate the savings and performance guarantees over the term of the EPC. It describes the information that should be included to support the plan. It states that "the reference to the IPMVP is intended to provide an independent source and reference of measurement and verification, and provide assurance to Customers that the ESCO is following recognised international practice with respect to M&V". This guidance should be interpreted to refer to the most current revision of the IPMVP which is March 2002, at the time of writing this BPG-M&V.

Chapter 4 is the commentary on the *National Standard Energy Performance Contract*. The following are the major references to M&V

- Advice is given on the conduct of a Works Specification Meeting to finalise all details before proceeding with the preparation of a detailed works specification. The meeting includes finalisation of the M&V Plan.
- Clause 5.4 – *The Customer must notify the ESCO*. This is an important clause for the management of non-routine Baseline Adjustments. The guide states that the intent of the clause is twofold: (1) to determine whether any action on the premises, either by the Customer or an outside entity, will impact on energy savings from the ECMs; and (2) to give the ESCO adequate time, if possible, to take corrective action to ensure savings are maintained, given any such occurrences.
- Clause 7 – *Performance Guarantee* has a number of important subclauses that deal with the key M&V issues to be managed in the EPC.
  - Clause 7.2 – *Monitoring and Verification:* In the context within which it is used, the term "monitoring" should be interpreted the same as "measurement". A general savings formula is quoted which has a different form to the one quoted in Chapter 2 of this BPG-M&V but it has the same intent. Readers are advised that it is best to use the current general formula presented in Chapter 2 of this Guide. Details are described of what should be provided in the M&V Plan. Guidance is given on the importance of arriving at a balance between M&V cost and accuracy.
  - Clause 7.2 (d) – *The Customer must assist:* This encourages co-operation in providing information about changes that may require Baseline Adjustments.
  - Clause 7.4 (d) – *Calculation of guaranteed energy savings:* This emphasises the importance of describing the savings determination method, data collection, data use, and calculations when establishing the Baseline Energy for the post-retrofit period. The advice highlights the importance of obtaining agreement on the adjustments that will be made and how they will be made.
  - Clause 7.5 (d) – *Savings Shortfall* and Clause 7.5 (e) - *Excess Savings Shortfall* provide guidance on how to manage savings shortfalls and excess savings.

- o Clause 8 – *Baseline Adjustments:* This explains the rationale and basis of M&V and how baseline adjustments are made. The advice is based on IPMVP 1997. Users of the BPG-EPC are advised to refer to this new Guide (BPG-M&V), for updated explanations of the M&V savings determination processes and on how routine adjustments and (non-routine) Baseline Adjustments are made. Users of the BPG-EPC should note that the term "baseline adjustments" in the BPG-EPC includes the routine adjustments and (non-routine) Baseline Adjustments described in the BPG-M&V. The table of M&V Options provided in Appendix 10 of the BPG-EPC is based on IPMVP 1997 and should not be used.
- o Clause 8.1: – *Customer to provide monthly report on changes affecting baseline.* Customers have full responsibility to advise the ESCO as soon as the Customer becomes aware of potential changes that could require a non-routine Baseline Adjustment. A sample Baseline Adjustment checklist is provided in Appendix 8 of the BPG-EPC.
- o Clause 8.3: – *ESCO to determine effect on baseline and guaranteed energy savings*. This is required to manage non-routine Baseline Adjustments

The major differences between the M&V described in the BPG-EPC and this new BPG-M&V is that the BPG-EPC is based on IPMVP 1997 and the new Guide is based on IPMVP 2001 (Revised March 2002). The major differences are (refer to Appendix 2):

- The use of "baseyear" instead of "baseline" when referring to a defined period in the pre-retrofit period. The use of "baseline period" should be replaced by "baseyear period". The use of "baseline energy" should be replaced by "baseyear energy" when it refers to the energy measured in the pre-retrofit period. The term "Baseline Energy" should be used only to refer to the estimated "business as usual" energy in the post-retrofit period.
- The use of Baseline Adjustments for only non-routine adjustments instead of using the term to include both non-routine adjustments and non-routine adjustments.
- Option A in IPMVP 2001 (March 2002) is "partially measured retrofit isolation" where "partial measurement" means that some but not all parameters maybe stipulated. Option A in IPMVP 1997 allowed full stipulation.

What you should remember about M&V for EPCs

- The AEPCA standard contract documents include the necessary M&V obligations to determine energy savings in Energy Performance Contracting arrangements.
- The BPG-EPC provides guidance on how to satisfy the M&V obligations in the EPC and DFSA documents.
- This Guide is a companion document to the BPG-EPC providing additional conceptual and operational details applicable to M&V for EPCs.
- Since the BPG-EPC was produced in early 2001, a major revision of the IPMVP (in March 2002) and the final version of ASHRAE Guideline 14-2002 have been released.
- This latest version of the IPMVP has introduced some new terms and definitions that are adopted in this BPG-M&V: (1) use "baseyear period" instead of "baseline period"; (2) use "baseyear energy" instead of "baseline energy" when referring to the pre-retrofit period; (3) use "Baseline Energy" for "business as usual energy" in the post-retrofit period; (4) use "Baseline Adjustments" to refer to non-routine adjustments only; (5) full stipulation cannot be used for Option A.
- This BPG-M&V also introduces the concept of "Cost Avoidance" which is not used in the BPG-EPC.

CHAPTER 10: M&V FOR PROJECTS OTHER THAN EPC

“Measure your energy savings by managing your projects”

M&V for in-house energy savings projects

Facility and Energy Managers have been monitoring energy consumption and demand in buildings and campuses for many years.

There are compelling incentives and demands on both public and private sector facility owners/managers to increase the discipline, rigour, and transparency of how they manage and report on-going energy performance of their facilities. Reasons include:

1. increasing pressures on budgets for cost reduction
2. increasing demands for performance measurement and accountability against targets
3. increasing awareness of the economic, environmental, health and social costs of greenhouse gas emissions (GHG)
4. increasing compliance requirements from governments to reduce GHG emissions.

This Guide can be used to help you assess the way you manage and report on-going performance of your facilities. The single most important message in this Guide is that you should report on-going performance using the concepts of adjusted Baselines, “avoided energy” and “cost avoidance”. In general, energy performance should not be reported without adjustments for changes in conditions between reporting periods. Energy reporting using M&V principles and processes provides more reliable information from which energy decisions can be made. In turn, this will improve identification of real opportunities for saving energy and the cost-effectiveness of plans and actions to improve energy performance.

This Guide can also be used to improve the way in-house energy savings projects are planned and implemented. The formality, detail and cost of M&V can be easily adapted to your specific requirements. M&V processes, even for small projects, introduce additional discipline in planning and managing the project, and will assist you obtain funding and approval. The improved achievement and reporting of savings outcomes of each project will increase your credibility with management and make it easier to obtain funding and approval for your next project.

The same M&V techniques apply to energy savings projects you may implement with your own resources, with parts of the work contracted out, or with the complete work contracted out under various contractual arrangements, with or without energy savings guarantees (EPC).

The Whole-Facility Option C approach is generally best for managing and reporting overall facility energy performance and Greenhouse Gas abatement. Monthly or quarterly utility billing data is available and weather data can be purchased from the Bureau of Meteorology or specialist providers of weather data. Administrative and operational records should be available to identify and quantify changes in the operational environment. Software tools are available to manage the data, create Baseline Models, estimate Baseline Energy, and produce reports. Options A and/or B are usually the most appropriate for energy savings projects with equipment, plant, and/or maintenance upgrades. In this case additional metering may be required for retrofit isolation from the rest of the facilities. However, the cost of isolation metering can quite often be justified by also using it for other purposes, such as energy accounting and reporting.

The essential first step is to evaluate your policies, procedures, processes and systems for collecting and analysing energy data as well as operating data. The completeness and quality of your historical data will determine what you can analyse and investigate. The capabilities of the systems and software tools you use will determine how thoroughly and broadly you can undertake the analysis. Your in-house knowledge, experience and skills will determine whether you need external assistance in setting up business processes to manage and analyse your data.

A number of software applications can help you collect, enter, store and analyse your energy data, and report on energy performance, energy and cost saving and greenhouse gas emissions. Spreadsheets can be used extensively to perform these functions for smaller sites. Professional energy accounting software is available to assist you to perform these functions and to perform the M&V Baseline modelling and other savings determination calculations.

The example in Appendix 6 can be used for in-house reporting as well as for a multi-site portfolio energy reduction programs. The same M&V techniques can be used to determine energy reductions from changes in utilisation, operation and maintenance of your facility.

M&V for multi-site types of energy savings projects

A number of energy savings projects involve end-use equipment replacements or upgrades across a number of sites with similar facilities and energy subsystems. Examples of these multi-site energy savings projects are:

- public or private sector schools in a region or State
- hospitals in an administrative area of a State Health Department or owned by a private sector operator
- police stations or court houses
- restaurants belonging to a chain of restaurants
- public or private sector buildings owned or managed by a Portfolio Manager
- similar groups of buildings and facilities owned or leased by a Local Government body

For these types of multi-site projects, the potential energy savings for each site may be relatively small but the aggregated savings over the portfolio of sites may be significant. Consequently, it is not cost-effective for the owners, energy management consultants or ESCOs to conduct an in-depth investigation of the energy conservation opportunities for each of the sites. Instead they may rely on the similarity of facilities in groups of buildings to investigate samples of buildings in each group and then to propose the same ECM or a range of ECMs for each group of buildings. An experienced ESCO may use information from similar buildings to estimate the project cost, investment and savings.

The same M&V techniques used for sites with relatively large energy savings should be used but greater care has to be taken in balancing M&V savings uncertainty and costs. Normal M&V guidance is that a site-specific M&V Plan should be prepared. For multi-site projects a project-specific M&V Plan can be prepared for a group of sites with similar facilities and ECMs, however care has to be taken with managing sampling errors and other errors from the differences in ECM savings performance of individual sites. The FEMP M&V Guidelines Version 2.2 refers briefly to M&V Plans for these types of multi-site projects in Section 1 Chapter 4 Section 4.1.

These types of projects would most likely use Option A and/or B. Stipulations can be used to reduce M&V costs and simplify procedures. However, improperly used, stipulations can give M&V results undeserved credibility. The FEMP M&V Guidelines Version 2.2 provide guidance on the use of stipulations in “Detailed Guidelines for FEMP M&V Option A”, Section 3.

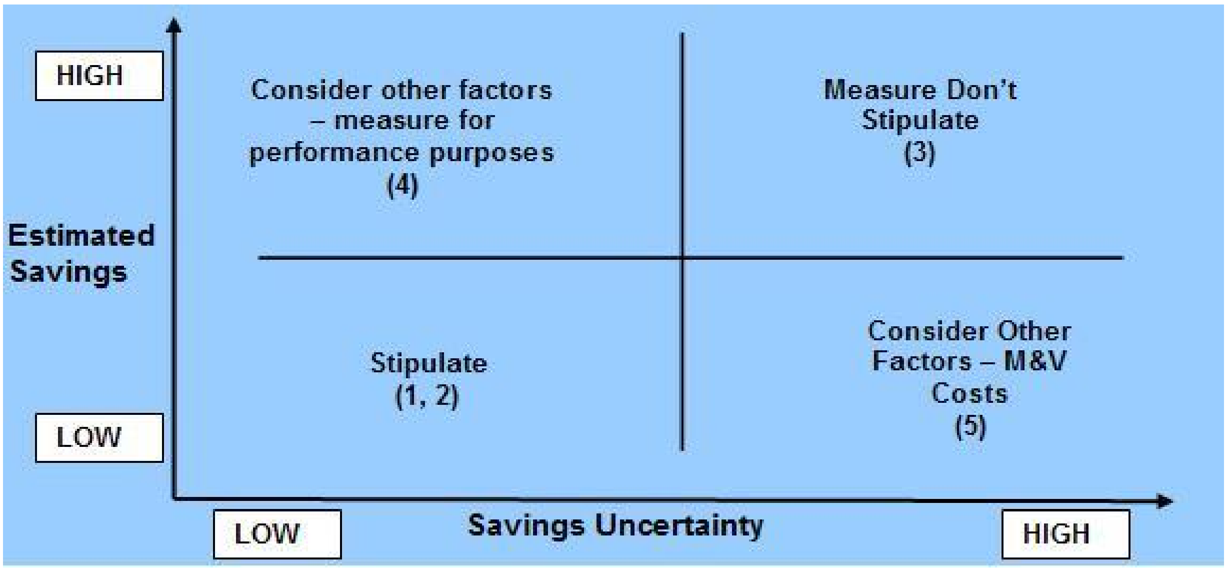


Figure 10.1 Measure versus Stipulate

The key aspects that should be evaluated when deciding whether to use stipulations and how to use them effectively in an M&V Plan are:

- the magnitude of the ECM's savings
- availability of reliable information
- project's likelihood of success
- uncertainty of the stipulated parameter and its contribution to overall project uncertainty
- the cost of measurement
- responsibilities of the ESCO and the facility owner/manager

Figure 10.1 illustrates the relationships between savings uncertainty, magnitude of savings, and whether stipulation is recommended.Several "rules of thumb" that flow from these relationships are as follows (refer to numbers in Figure 10.1)

1. The most certain and predictable parameters can be estimated and stipulated without significantly increasing uncertainty.
2. Stipulating parameters that represent a small degree of uncertainty and of overall savings will not significantly increase uncertainty.
3. Parameters that represent a higher percentage of project savings and uncertainty should be measured.
4. If estimated savings are high but uncertainty is low, measurement may not be necessary.
5. If estimated savings are small and uncertainty is high, stipulation would only shift risk to the facility owner/manager, and consideration of whether the ECM is worthwhile might be warranted.

Parameters that can vary over time because of weather, performance degradation, occupant behaviour, or other factors will always be uncertain. Whether these values should be measured or stipulated depends on who will assume the uncertainty risk.

The parties involved in a single or multi-site energy savings project which has relatively low savings potential and low savings uncertainty may consider using full stipulation. This is a commercial decision that can only be made by the parties considering the merits and risks of continuing with the project.

M&V for other types of programs

There are a number of other applications of M&V protocols and guidelines that are not addressed by this Guide. Users of this Guide may be interested in the following IPMVP documents that have been released or are planned for future consideration and release:

- IPMVP Volume II, entitled "Concepts and Practices for Improved Indoor Environmental Quality' – latest release is the revised edition dated March 2002
- IPMVP Volume III, entitled "Concepts and Options for Determining Energy Savings in New Construction' – first released in April 2003
- IPMVP Volume III, entitled "Concepts and Practices for Determining Energy Savings in New Renewable Energy Technologies Applications" – first released in August 2003
- IPMVP documents on Distributed Generation, Demand Response Programs and Emissions Abatement may be available at some time in the future

What you should remember about M&V for other energy savings projects

- M&V concepts and methodologies can be used to determine energy savings for in-house projects and multi-site projects
- M&V concepts and methodologies can be used for renewable energy projects, new construction, demand response programs, emissions abatement, and similar projects.
- Report your on-going performance using the M&V concepts of adjustments, "avoided energy" and "cost avoidance".
- The same M&V techniques for determining and verifying savings apply to all types of energy savings projects, irrespective of how they are implemented.
- The Option C approach is generally best for managing and reporting overall facility energy performance and GHGas abatement.
- Options A and/or B are the most appropriate for energy savings projects with equipment, plant, and/or maintenance upgrades
- The essential first step is to improve collection and management of energy data
- For multi-site projects with similar groups of sites with relatively small potential energy savings per site a project-specific M&V Plan with sampling of sites may be satisfactory.
- If your multi-site energy savings project has relatively low savings potential and low savings uncertainty, you may consider using full stipulation but you should also consider the merits and risks of continuing with the project

CHAPTER 11: M&V FOR PORTFOLIO ENERGY PERFORMANCE REPORTING

"Measure your real energy performance"

Background

This Guide can be used by those who are involved in developing sustainable energy policies, strategies and plans for reducing energy and/or GHG emissions across a multi-site portfolio (or just a single site) of facilities and for annual reporting of the success or otherwise in achieving annual reduction targets. This applies particularly to Commonwealth and State Governments who have multiple Agencies with many buildings and campuses. It also applies to private sector portfolio managers with responsibilities for managing and reporting energy performance and GHG abatement for a portfolio of diverse facilities over many geographical locations.

Portfolio energy performance determination issues

Common practice is to evaluate energy performance against reduction targets on an annual basis by subtracting annual consumption for the current reporting period from the annual consumption for a base reference period. This evaluation would be valid if there were no material changes in the influences of weather and other conditions, between the current reporting year and the base reference year, on the energy performances of facilities in the portfolio.

As discussed in Chapter 4, weather usually has a major influence on energy consumption. Weather severity, measured by the number of Cooling Degree Days (CDD) and Heating Degree Days (HDD), changes from year to year. If the change in annual weather severity between the current reporting year and the base reference year is materially different, the energy performance evaluation would have an error related to the difference.

This error could be removed by using a Baseline Model for each site with weather severity as the explanatory variable to calculate the Baseline Energy for each site for the current reporting period. The energy reduction for the current reporting period would be calculated by subtracting the measured annual energy consumption for each site for the current reporting year from the estimated annual Baseline Energy consumption for each site for the current reporting year.

Across a portfolio of buildings it is inevitable that there are also physical changes to the buildings, changes in operating conditions, and changes from energy retrofits. These also create errors in the energy comparison between the current reporting year and the base reference year. Predictable changes could be tested and used for additional routine adjustments to the base reference year energy consumption by adding them as explanatory variables to the Baseline Model for each site. Baseline Adjustments could be used to adjust Baseline Energy for each site for unpredictable changes between the base reference year and the current reporting year.

These M&V adjustment processes and calculations for determining energy reductions described above are identical to those described in Chapters 4 and 5, except for some inherent differences between a portfolio energy performance reporting program and an energy savings project:

- For a portfolio energy performance reporting program, the energy reduction determination and reporting is done annually for a number of reporting years whereas for an energy savings project the energy savings determination could be done once.
- The annual portfolio energy performance determination is done between a pre-determined base reference year and one or more subsequent reporting years. The 12-reporting periods are usually financial years.

- A portfolio energy performance reporting program does not have an ECM installation period. Consequently, the end of the base reference year period is the start of the first reporting year period and the start of each subsequent reporting year period follows the end of each previous reporting year period.
- For a portfolio energy performance reporting program, the start and end of the baseyear period is set by the predetermined base reference year period whereas for an energy savings project the start and end of the baseyear period is determined during the creation of the Baseline Model.
- For a portfolio energy performance reporting program, the baseyear energy data would be the energy data for the base reference year. If there was missing or "bad" data, it may be necessary to use some data points before the start of the base reference year to create a statistically valid Baseline Model. For an energy savings project, there is more flexibility in selecting the baseyear data points provided that no data from the installation period is used and a minimum of 12 representative data points are used.
- The Baseyear Model Creation Guidelines described in Chapter 5 and detailed in Appendix 4 apply to an energy reduction reporting program but some of the key criteria, such as the Net Determination Bias and the Monthly Mean Error, may have to be relaxed because (1) there is less flexibility in selecting the baseyear period and (2) it may not be cost-effective to explore using additional explanatory variables, other than weather severity, to improve the statistical validity of the Baseline Model.
- Baseyear conditions for each site should be recorded so that Baseline Adjustments may be considered. However, it would be expected that only major changes in a site or in the portfolio would be used to make Baseline Adjustments at the site level and portfolio level, respectively. For example, a Baseline Adjustment at the portfolio level should be made for a building that was sold/closed or purchased/opened during a reporting year. A Baseline Adjustment at the site-level should be made if an energy retrofit was completed during a reporting period.
- The annual performance period for a portfolio energy performance reporting project is the annual reporting period for the project. The number of annual reporting periods is determined by the requirements of the portfolio energy performance reporting program.

The decision on whether it is necessary or worthwhile to expend time, effort and cost to eliminate or minimise error components from weather severity and other influence factors depends on balancing the required accuracy and potential costs. Program-specific and site-specific judgements have to be made on whether it is acceptable to ignore some or all of the error components and how much action, if any, should be taken to minimise them. This is influenced by the accuracy and confidence level requirements of the program reporting and the potential magnitude of the error components, as well as the cost-benefits of taking any action.

Weather-Corrected Energy Performance Determination

An example is presented in in Appendix 6 to illustrate how standard M&V techniques can be used correct energy performance for weather-based errors. The example uses one electricity meter in one building selected from a portfolio of buildings. The selected building and a large number of other buildings in the portfolio are located in a Capital city in Australia.

The base reference year for the portfolio energy performance reporting program is 2000/2001 and the reporting year is 2001/2002. Monthly electricity billing data is available for these two years and daily high and low temperature data is available from the closest Bureau of Meteorology weather station. The summer of the base reference year was abnormally hot and the summer of the reporting year was much cooler. There were concerns that this weather difference could affect the credibility of the energy perfomance determination and reporting for this site and the protfolio of sites.

During the reporting year, there had been no major energy retrofits and no material changes to the building operations and maintenance.

Details of the energy reduction determination process are presented in Appendix 6. The following are the steps used in the process.

The first step is to compare monthly electricity consumption data for the two periods as this highlights year-to-year monthly and seasonal differences. The comparison showed significant differences in consumptions especially for the summer months November to February (refer to Figure A6.1 in Appendix 6). There had been no energy retrofits or other operational changes that could account for the significant year-on-year monthly differences in consumptions.

The reduction in consumption for the reporting year relative to the base reference year without any weather correction was as follows:

Total Annual Consumption for 2000/2001 in kWh	1,605,138
Total Annual Consumption for 2001/2002 in kWh	1,197,135
Consumption Reduction before Weather Correction	408,003
Percentage Reduction relative to Base Reference Year……….25%	

The second step was to examine the variations in the weather data - daily high and low temperature - over the two years. It was too difficult to conclude anything from the daily variation of the temperature data (refer to Figure A6.2 in Appendix 6).

The third step was to calculate the Cooling Degree Days (CDD), relative to the standard Balance Point of 18.3^{o}C, and compare the year-to-year monthly differences. Comparison of the year-to-year monthly consumptions and number of CDDs showed that the largest differences in monthly consumptions occurred when there were the largest differences in number of CDDs (refer to Figures A6.1 and A6.3 in Appendix 6). There was a significant reduction in the Total Annual CDDs in the reporting year relative to the base reference year:

Total Annual CDDs for 2000/2000	858
Total Annual CDDs for 2001/2002	379
Difference in Annual CDDs	479
Percentage Reduction in CDDs relative to Base Reference Year…..55.83%	

It was concluded that the significant difference in annual CDDs could account for a significant proportion of the 25.42% reduction in annual consumption calculated above.

The fourth step was to use a Whole-Building Option C savings determination method to find out if a statistically valid Baseline Model could be created that defined any relationships between monthly consumption and monthly weather severity. An M&V software tool was used to create a Baseline Model for the electricity meter by performing a linear regression between monthly electricity consumption data and weather severity for the base reference year of 2000/2001.

A Baseline Model was created using Cooling Degree Days (CDD) as the explanatory variable. The Cooling Balance Point for the specific model was 15.3^{o}C.

The Baseline Model is expressed by the following equation

Baseline (kWh) = 471.08 x No of Days + 1,026.24 x No of CDDs

The interpretation of the Baseline equation is that during the base reference year period the base daily consumption for this meter was 471.08 kWh per day and the consumption variation caused by weather variation was 1,026.24 kWh/CDD. The model is statistically valid as descibed (refer to Appendix 6 for the statistical validity indicators)

The fifth step is to use the Baseline Model equation to estimate Baseline Energy for the reporting year - the energy that would have been consumed if the weather in the base reference year had been the same as the weather in the reporting year. This is done by calculating the CDDs at the model's specific Cooling Balance Point of 15.3^{o}C from the daily high and low temperature data for the reporting year and then applying the number of days and the number of CDDs to the Baseline Model equation.

The reduction in consumption for the reporting year relative to weather-corrected base reference year consumption is as follows:

Total Weather-Corrected Annual Baseline Energy for 2001/2002 in kWh	1,079,412
Total Actual Annual Consumption for 2001/2002 in kWh	1,197,135
Annual Consumption Increase After Weather Correction	117,723
Percentage Increase relative to Weather-Corrected Baseline……………….11%	

The sixth step is to report that annual consumption for this meter for the reporting year has **increased** by about 118,000 kWh (11%) rather than having **decreased** by 408,000 kWh (25%) as originally calculated.

This example shows the potential for error in an energy performance determination process by ignoring weather-correction.

In general, routine adjustments for other predictable influence factors and/or Baseline Adjustments for unpredictable changes may be required. However, the most common adjustment that should be made is weather correction. The decision of whether to expend time, effort and money on more extensive adjustments depends on the purpose, required accuracy, required confidence level and the cost-benefit of taking action.

Aggregated Portfolio Energy Performance

Each site in the portfolio should be analysed to see whether the energy data for the base reference year has to be adjusted for weather differences or for differences in other non-ECM conditions before calculating the reduction or increase in energy consumption. In some cases there will be no need for weather correction but there may be a need to correct for other non-ECM factors.

The reductions and increases across all sites can be aggregated and then compared to the target reduction for the reporting period.

Implementation and Cost Issues

The most significant costs in determining energy reductions for a multi-site portfolio are the collection and recording of billing data.

Billing data is not normally available from utility suppliers in a standard electronic format and some utility suppliers can only provide data in hardcopy bills. There are no Australian or industry standards for the presentation of utility billing data to end-use customers.

For multi-site owners with centralised payment centres it is easier to arrange for the payment centre to capture billing data at the time of payment. It is very difficult for payments centres to retrieve billing data after they have filed their payments documentation. Payments staff do not normally record consumption data. There would be additional costs in having Payments staff capture billing consumption for subsequent use.

For multi-site owners with de-centralised payments centres it is much more difficult to arrange for all payment centres to capture billing data at the time of payment. Business processes should be setup to reliably capture, validate, and store data at a central point for easy access. Various parts of the organisation (e.g. separate Government Agencies) may have their own business processes for capturing, validating and storing the billing data, which are not compatible across all parts of the organisation. The minimum that should be done is to establish compatibility standards for transferring captured data to a central point where centralised analysis is conducted.

The costs in arranging timely, reliable, consistent, and complete capture of all multi-site billing data should be justified by the needs of the organisation and its parts to periodically report on energy and cost performance across the multi-site portfolio. This cost should not be charged against the portfolio energy performance reporting program, except for any additional costs that can be directly attributable to it.

The cost of recording and reporting major unpredictable events or changes that impact site consumptions, which may require Baseline Adjustments, should be absorbed in the normal operation and administration of each site.

The data required for a multi-site portfolio energy performance reporting program is not extensive but the quality and completeness of the data is very important. The following are essential:

- Start and end dates of the billing periods (or billing end date and number of billing days in the billing period) are captured correctly
- Consumption data is captured accurately and completely
- Billing data estimated by the utility provider should be highlighted and any information on how the estimation was done should be recorded.
- If the end-use customer estimates any missing or erroneous data, the details should be recorded.
- The billing data is stored in a secure, consistent and easily accessible way.

The required weather data is available at minimal cost from the Bureau of Meteorology or pre-processed from specialist providers of weather data for the energy industry.

The time and effort required to create and document site-specific Baseline Models and to determine the energy performance for a reasonably sized portfolio may be about 2 to 3 weeks, if the billing data is reasonably complete and is available in an easily accessible consistent format. The conduct and documentation of the energy performance determination for the portfolio for each subsequent reporting year may require 1 to 2 weeks.

The cost of creating and using Baseline Models for weather correction is reasonably minimal, if the business processes for capturing, validating and storing billing data are in place. The decision whether weather correction is used depends finally on the required quality, accuracy and confidence in the reported energy reductions.

What you should remember about portfolio energy performance programs

- For a multi-site portfolio energy reduction program, you should consider using M&V weather-corrected methods to reduce potential errors.
- The decision on whether it is necessary to expend time, and cost to minimise errors depends on balancing the required accuracy and potential costs.
- The most significant parts of the work and costs in determining energy reductions for a multi-site portfolio are the collection and recording of billing data.
- The time and effort required to create and document site-specific Baseline Models for a reasonably sized portfolio may be about 2 to 3 weeks, if the billing data is reasonably complete and available in an easily accessible consistent format.
- The conduct and documentation of an annual energy reduction determination for a reasonably-sized portfolio may require about 1 to 2 weeks for each reporting year, if the billing data is reasonably complete and available in an easily accessible and consistent format.

CHAPTER 12: M&V FREQUENTLY ASKED QUESTIONS

Background

This Chapter presents brief guidance on a number of common issues and questions that arise during the planning and implementation of a savings determination project. Some of the issues have already been mentioned in previous Chapters but have been included in this Chapter to highlight their common occurrence and to provide a wider context for the answer.

The information in this Section has been adapted from a number of sources (including IPMVP Volume 1 and the FAQ on the IPMVP website http://www.ipmvp.org) and from practical experience.

How can M&V be used as a risk management strategy?

Measurement and verification works as a risk management tool in performance-based energy efficiency projects. Financial payments are tied to the performance of the project (energy savings) and by developing a cost-effective M&V strategy the customer and the contractor can reduce their respective risks. The ESCO can prove the savings are real and the customer can hold the ESCO accountable if there is a shortfall.

How does M&V increase energy efficiency savings?

Continuous monitoring helps in diagnosing and correcting problems that would have gone unnoticed in the absence of a M&V Plan, thus saving additional energy.

Why is there a need for a standard M&V protocol?

To be able to use unbiased, technically rigorous, and cost-effective methods to measure and verify energy savings.

To allow savings comparisons between projects with different ECMs, in different facilities and locations, by different ESCOs.

How does standard M&V protocol help attract investments for energy efficiency projects?

Financial institutions don't like uncertainty and standard M&V protocols provide open, transparent, and replicable methods of calculating energy savings for any type of energy conservation measure. This helps in reducing uncertainties associated with using different M&V protocols for different projects and reduces the possibility of disagreements over the type of protocol used.

What is the difference between IPMVP Volume 1 and ASHRAE Guideline 14P?

These are complementary documents that provide guidance and instruction to those interested in quantifying the results from energy savings projects (refer to Appendix 1).

IPMVP and ASHRAE differ by design in these key areas:

- IPMVP is a framework of definitions and broad approaches whereas ASHRAE Guideline 14 provides details on preparing and implementing M&V Plans within a similar framework.
- IPMVP makes a provision for stipulation and limited metering under Option A whereas ASHRAE requires metering for all Options.
- IPMVP’s discussions on balancing of uncertainty and cost (Volume 1 Chapter 4.11) are enhanced by ASHRAE’s definition of ways to quantify uncertainty, so M&V design decisions can consider costs in light of the best available methods for quantifying uncertainty.

What is the difference between IPMVP Volume 1 and FEMP M&V Guidelines?

These are complementary documents that provide guidance and instruction to those interested in quantifying the results from energy savings projects (refer to Appendix 1).

IPMVP and FEMP M&V Guidelines differ by design in these key areas:

- IPMVP is a framework of definitions and broad approaches whereas FEMP M&V Guidelines are an application document, based originally on the 1997 version of IPMVP, specifically prepared for the U.S. Federal Agencies. FEMP M&V Guidelines also provide more details on the application of different M&V Options for specific ECMs.
- IPMVP requires the use of limited metering under Option A whereas FEMP M&V Guidelines allow full stipulation under special circumstances (refer to Appendix 1 and Chapter 10)

Who is responsible for savings performance?

The contractor and the facility owner/manager share the responsibility for savings performance of ECMs. If there are no stipulations, the contractor assumes the full risk of savings performance, except for material changes to non-ECM conditions that justify Baseline Adjustments. Before the contractual arrangement is agreed both parties should be fully aware of the guaranteed/promised/expected savings, the assumptions behind the savings estimate, and the division of responsibilities between the parties for achieving the estimated savings.

If the savings are not achieved initially or are not persistent over time, the two parties have to investigate the causes and, if possible, agree on corrective actions to be taken to restore the expected savings performance.

M&V has no responsibility for the realised savings performance of the ECMs. M&V has provides appropriate advice during the project to minimise the savings uncertainties and then to implement the savings determination processes as specified and defined in the M&V Plan.

Who is responsible for energy engineering standards compliance?

Meeting the minimum energy engineering standards is part of the ECM engineering responsibilities. The facility owner/manager should ensure that the ECM contractor satisfies the standards that apply to the specific facility. M&V has no responsibility but the requirement to report on compliance with standards could be done if it is included in the M&V Plan.

Who is responsible for maintaining required operating conditions?

An energy efficiency project should not compromise the operations of the facility to which it is applied without the agreement of the facility owner/manager. This is a shared responsibility of the ECM contractor and the facility owner/manager.

M&V has no responsibility for operating conditions. The M&V Plan should record the agreed conditions to be maintained and compliance with the requirements can be reported if required.

What is a typical length of the performance period?

This is determined by the nature of the ECM, the selected M&V Option, and the contractual and debt repayment arrangements. These issues should be considered during the preparation of the M&V Plan and documented in the Plan.

M&V is responsible for providing advice during the planning process and then for conducting the agreed M&V for the length of the Performance Period.

If the realised savings are being achieved at the end of the first year of the post-retrofit period, there is a temptation not to continue with the savings determination for subsequent years of the Performance Period. This is not an M&V issue but a contracting, financial risk management, and/or performance risk management issue.

Who conducts M&V?

This depends on the specific project circumstances, which include:

- contracting arrangements
- division of responsibilities
- number, type and complexities of the ECMs
- complexity of the required M&V
- availability of M&V knowledge, experience, skills, and specialised M&V tools
- requirement for transparency and independence for the savings determination

It is common practice for the ESCO to take responsibility for planning and implementing the M&V. It is advisable that the person(s) within the contracting organisation are given sufficient independence and the required resources for this. The issue of internal independence should be managed like any other quality management issue where transparency is required.

Facility owner/managers do not normally conduct M&V for an energy performance contract as they seldom have the necessary knowledge, skills, experience or specialised resources, but could do so for an in-house project. They could use third-party M&V specialists for in-house projects or for providing independent advice during the course of an energy performance contract.

Both parties could agree to use a third-party M&V specialist to provide advice during the planning of the M&V and/or to conduct the M&V savings determination processes. The advantage of using a third-party specialist is the transparency and independence of the reported results.

An accreditation program for M&V professionals has been created by the IPMVP and the Association of Energy Engineers (USA) http://www.ipmvp.org/services.html#CMVP Accredited M&V professionals are referred to as Certified Measurement and Verification Professionals (CMVP).

At the time of writing this Guide there is no equivalent accreditation in Australia. However, it is expected that an M&V accreditation process will be developed at some future date.Pending the development of an Australian M&V accreditation process, AEPCA recognises the international CMVP qualification http://www.aepca.asn.au/

REFERENCES

AEPCA: "*A Best Practice Guide to Energy Performance Contracts*", 2001 http://www.aepca.asn.au/

ASHRAE Guideline 14-2002: *"Measurement of Energy and Demand Savings"*, final release June 2002, available, http://www.ashrae.org/

Cowan, J: "*Fundamentals of Measurement & Verification: Applying the New IPMVP*", Lecturer course documentation for Certified Measurement and Verification Professional (CMVP) program, IPMVP and Association of Energy Engineers (AEE) Certification Program, http://www.ipmvp.org/services.html - CMVP

FEMP Draft M&V Plan Outline, "Draft M&V Plan Outline", October 2003, http://ateam.lbl.gov/mv/#DraftDocs

FEMP M&V Guidelines, "*The M&V Guidelines: Measurement and Verification for Federal Energy Management Projects",* Version 2.2, September 2000, http://www.eere.energy.gov/femp/financing/espc/measguide.html

FEMP Option A Revision, *"Detailed Guidelines for FEMP M&V Option A"*, May 2002, http://ateam.lbl.gov/mv/docs/OptionADetailedGuidelines.pdf

FEMP M&V Planning Tool, *"M&V Planning Tool"* , June 2003, http://ateam.lbl.gov/mv/ - KeyDocs

FEMP Sample M&V Plans, "FEMP Sample M&V Plans for SuperESPC Projects" Draft, January 2001, http://ateam.lbl.gov/mv/#DraftDocs

Hansen, S.J, "Manual for Intelligent Energy Services", Fairmont Press, ISBN 0-88173-380-6, 2002.

IPMVP Volume I: *"Concepts and Options for Determining Energy Savings"*, revised edition March 2002, http://www.ipmvp.org/download.html

IPMVP Volume II: *"Concepts and Practices for Improving Indoor Environmental Quality"*, revised edition March 2002, http://www.ipmvp.org/download.html

IPMVP Volume III: *"Concepts and Options for Determining Energy Savings in New Construction"*, first released April 2003, http://www.ipmvp.org/download.html

IPMVP Volume III: *"Concepts and Practices for Determining Energy Savings in New Renewable Energy Technologies Applications*", first released August 2003, http://www.ipmvp.org/download.html

Kumar, V: "*International Performance Measurement & Verification Protocol*" PowerPoint Presentation, http://www.ipmvp.org/

Nicolosi, A. P: *"Proving the Savings: Measurement & Verification"*, Seminar on Energy Performance Contracting in Western Australia, Perth, Western Australia, October 2003. http://www.aepca.asn.au/page16.html

Pacific Northwest National Laboratory (PNL), *"FEMP M&V Instructional Toolkit"*, http://metering.pnl.gov/MandV/FEMPMVtool.htm

Sharp, T: *"Practical Measurement and Verification: The Project Rules",* Presentation at Energy 2001 - Energy Efficiency Workshop & Exposition, Kansas City, Missouri, June 2001.

Waltz, J. P: *"Management ,Measurement &Verification of Performance Contracting"*, Fairmont Press, ISBN 0-88173-271-0, 2003.

APPENDIX 1: M&V PROTOCOLS AND GUIDELINES

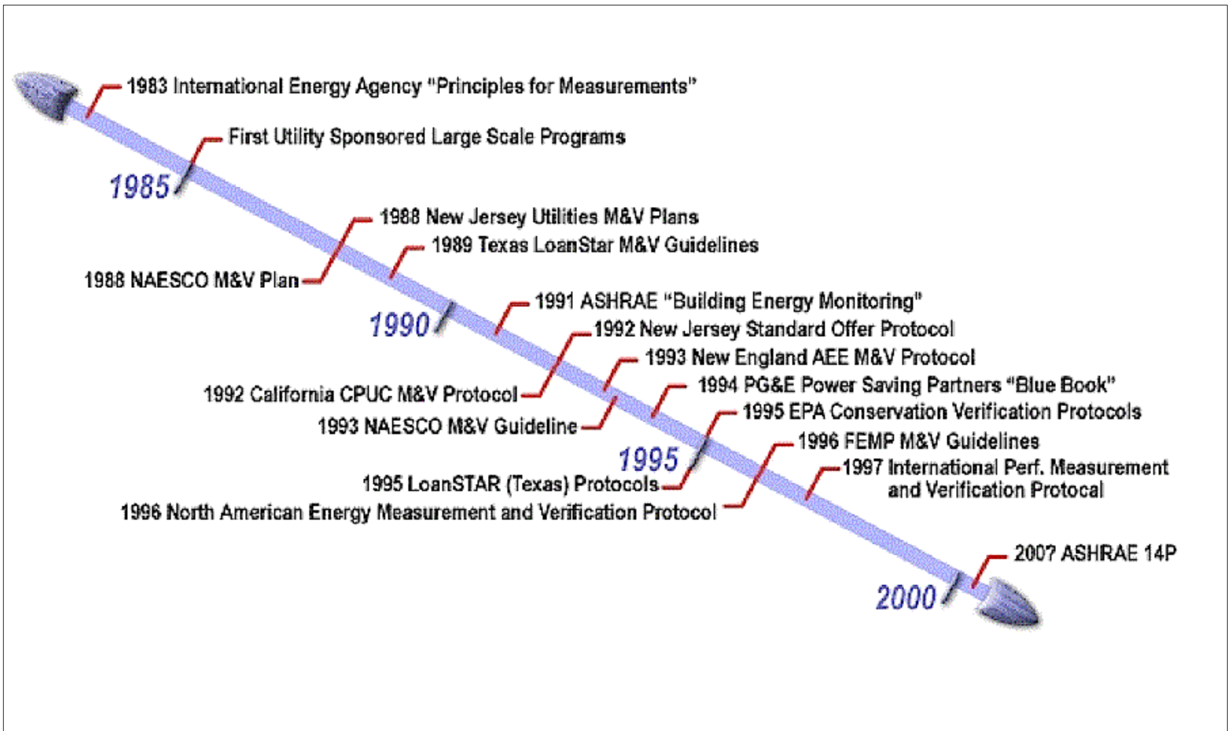
Evolution of M&V Protocols and Guidelines

The following description of the evolution of M&V Protocols and Guidelines and the graphical timeline below are adapted from the IPMVP 2001 (March 2002), the FEMP M&V Guidelines Version 2.2 and the Pacific Northwest National Laboratory (PNL) FEMP M&V Instructional Toolkit.

The development of formal M&V Protocols and Guidelines was initiated by the increasing use of energy performance contracting in the USA during the 1980s and the 1990s. Energy performance contracting created the need to know how best to determine energy savings (and thus payment) in an accurate and repeatable manner. As shown in the timeline below, a variety of organizations developed documents with M&V concepts and procedures to suit the needs of the specific organisation, State constituencies or energy savings program. These M&V initiatives were centred initially around measurement principles and energy monitoring and then evolved into the unifying protocols that we see in place today.

The U.S. Congress authorized and encouraged Federal agencies - the largest single energy consumer in the United States - to make use of innovative contracting mechanisms to finance and implement energy efficiency improvements to help reduce the government's energy costs and meet Federal energy goals. The use of energy savings performance contracts (ESPCs) was authorized in the 1986 amendments to the National Energy Conservation Policy Act of 1978 (NECPA), which was further amended by the Energy Policy Act of 1992 (EPACT). The ESPCs are managed under the U.S. Federal Energy Management Program (FEMP), chartered in 1973 with the mandate to lead the government toward more efficient use of energy resources.

In the 1990s, investments in energy efficiency projects were less than expected due to the high uncertainty associated with future energy savings. This uncertainty arose, in part, from multiple and often inconsistent Measurement and Verification protocols. These inconsistencies resulted in a patchwork of engineering approaches to efficiency installations and measurement of savings.



In 1994, US Department of Energy initiated an effort to establish international consensus on methods to determine energy/water efficiency savings and thus promote third-party investment in energy efficiency projects. This initiative pulled together energy efficiency experts from North America in the beginning and later from all over the world. Australia did not participate. One of the larger goals of this initiative was to help create a secondary market for energy efficiency investments by developing a consistent set of M&V options applying to a range of energy efficiency measures in a uniform manner resulting in reliable savings over the term of the project.

The voluntary efforts of these international experts resulted in the publication of the North American Energy Measurement and Verification Protocol – **the NEMVP in 1996**. The NEMVP, for the first time, came up with a consistent definition of Options A, B, and C.

International Performance Measurement and Verification Protocol (IPMVP)

In 1997, an updated version of the protocol was published and was renamed the International Performance Measurement and Verification Protocol (IPMVP) to reflect the international nature of the protocol. Another landmark was that water was recognized as a critical resource at par with energy and M&V for water efficiency projects was included for the first time in the 1997 version. While the first version had three M&V Options, a new M&V Option D was included in the second version to recognize the industry practice of using energy simulation tools to determine energy savings, which are then verified by measuring energy use and calibrating the simulation model. The four M&V Options A through D have since become industry standard and are widely used both in the US and abroad. This version is referred to as IPMVP 1997.

In January 2001, the third version was published, with two volumes. The first volume was called IPMVP Volume I: Concepts and Options for Determining Energy Savings. It clarified the definition of Option A by removing any ambiguity relating to the use of stipulated values in the engineering calculations/models. IPMVP Volume II: Concepts and Practices for Improving Indoor Environmental Quality, was published concurrently with Volume I. This version is referred to as IPMVP 2001 (and sometimes as IPMVP 2000)

In September 2001, the Protocol Committee of the IPMVP (called Executive Committee at that time) decided to form a non-profit organization IPMVP Inc. (deriving its name from the flagship product) to maintain and update existing content and develop new content where IPMVP can add significant value.

In March 2002, revised editions of IPMVP Volumes 1 and 2 were published. This revised version is referred to in this Guide as IPMVP 2001 (March 2002)

In April 2003, IPMVP Volume III, entitled "Concepts and Options for Determining Energy Savings in New Construction' was first released.

In August 2003, IPMVP Volume III, entitled "Concepts and Practices for Determining Energy Savings in Renewable Energy Technologies Applications" was first released.

FEMP M&V Guidelines

Chartered in 1973, the Federal Energy Management Program's (FEMP) mandate is to lead the government toward more efficient use of energy resources. FEMP's challenge is to help agencies find smart energy-management solutions that will generate significant savings for taxpayers

The FEMP M&V Guideline follows the IPMVP, and provides guidance and methods for measuring and verifying the energy and cost savings associated with federal agency performance contract. It is intended for federal energy managers, federal procurement officers, and contractors implementing performance contracts at federal facilities. Assistance ids provided on choosing M&V methods that provide an appropriate level of accuracy to protect the project investment.

In 1996, the FEMP M&V Guidelines were first released as an application of the IPMVP (initially the NEMVP) to assist U.S. Federal Agencies in planning and conducting their M&V activities for energy performance contracting projects.

In September 2000, the updated FEMP M&V Guidelines Version 2.2 were published.

In May 2002, an update to the guidance for Option A, entitled "Detailed Guidelines for FEMP M&V Option A" was published to restore alignment to IPMVP 2001, which no longer allows full stipulation for Option A. The updated FEMP Option A guidelines are aligned with

IPMVP 2001, except for a couple of special cases where full stipulation is still allowed (Refer to Appendix 3).

ASHRAE Guideline 14 -2002

IPMVP is complemented by the work of ASHRAE who produced Guideline 14P – Measurement of Energy and Demand Savings, which was out for comment for a number of years.

In June 2002, the final document was approved and issued as ASHRAE Guideline 14-2002.

ASHRAE Guideline 14-2002 focuses on the measurement of energy and demand savings at a very technical level. In contrast, the IPMVP establishes a general framework and terminology for planning and implementing M&V activities.

Many users of this Guide will find difficulty in following the technical and mathematical details in ASHRAE Guideline 14-2002. M&V practitioners and professionals should use it as the definitive technical guide for measurement of energy and demand savings.

ASHRAE Guideline 14-2002 does not have the equivalent of IPMVP Option A and insist on full measurement. Despite this difference and some differences in terms, ASHRAE Guideline 14-2002 is compatible with Volume 1 of IPMVP 2001 (March 2002). This is facilitated by cross-membership between the IPMVP and ASHRAE Guideline 14 committees.

Disclaimers

International Performance Measurement and Verification Protocol (IPMVP)

Institutions such as the World Bank have found the Protocol beneficial and are incorporating it as a required part of energy efficiency projects. The IPMVP has been translated into many other languages.

You should be aware of the disclaimer in IPMVP which in part states *"The IPMVP does not create any legal rights or impose any legal obligations on any person or other legal entity. IPMVP has no legal authority or legal obligation to oversee, monitor or ensure compliance with provisions negotiated and included in contractual arrangements between third persons or third parties. It is the responsibility of the parties to a particular contract to reach agreement as to what, if any, of this protocol is included in the contract and to ensure compliance."*

ASHRAE Guideline 14

You should be aware of the disclaimer in ASHRAE Guideline 14-2002, which in part states *"ASHRAE publishes Guidelines in order to provide assistance to interested parties on issues that relate to the design, testing, application, and/or evaluation of products, concepts, and practices where there are may be more than one acceptable approach. Guidelines are not mandatory and only provide one source of information that may be helpful in any given situation."*

FEMP M&V Guidelines

The U.S. Federal Agencies have obligations to use the FEMP M&V Guidelines. Users in Australia should use their own judgement about using the FEMP M&V Guidelines.

APPENDIX 2: M&V PLAN OUTLINE

The M&V Plan Outline presented in this Appendix is an adaptation of the FEMP Draft M&V Plan Outline available at http://ateam.lbl.gov/mv/ and is provided for general guidance as a starting point on the preparation of project-specific M&V plans.

1. Executive Summary / M&V Overview

1.1 Annual Savings Overview

ECM	Electric Energy Savings (kWh)	Electric Demand Savings (kW)	Natural Gas Savings (MJ)	Water (kL)	Etc …	Etc …	O&M Cost Savings ($)	Annual Energy Cost Savings ($)	Total Annual Cost Savings ($)
Total Savings									
Total Site Usage*:									
% Total Site Usage Saved*:									

*Optional
Include all applicable fuels and commodities for project, such as: electric energy, electric demand, natural gas, LP gas, fuel oil, coal, water, etc.

1.2 M&V Approach Summary

ECM	ECM Description	M&V Option Used*	Summary of M&V Approach

*Reference M&V guideline used, for example: *Best Practice Guide to M&V of Energy Savings; International Performance Measurement & Verification Protocol (IPMVP) Volume I March 2002 M&V Guidelines: Measurement & Verification for Federal Energy Projects, Version 2.2*; *ASHRAE Guideline 14-2002*

2. Whole Project Data / Global Assumptions

2.1 Risk & Responsibilities

2.1.1 Summarise allocation of responsibility for key items related to M&V

2.1.2 Discuss agreed upon requirement for uncertainty analysis

2.2 Utility Rate Data

2.1.1 Utility rates for the baseyear period and explain use of any stipulated rates

2.1.2 Utility rates for the performance period including any agreed escalation/stipulation

2.3 Schedule & Reporting for Verification Activities

2.3.1 Define requirements for witnessing measurements

- Baseyear
- During commissioning
- Post-installation verification activities
- Performance Period

2.3.2 Define schedule of verification reporting activities

Item	Recommended Time	Owner Review and Acceptance Period
Final Commissioning Plan and Final M&V Plan	With Works Specification	Typically 30 days
Commissioning Report	As per EPC contract	Typically 30 days
Post-Installation Report	As per EPC contract	Typically 30 days
Annual Report	Typically 30 to 60 days after end of annual performance period	Typically 30 days

2.3.3 Define content and format of reports

- Commissioning Report
- Post-installation report
- Post-installation verification activities
- Periodic (Annual) M&V savings performance reports

2.4 O&M Reporting Requirements

2.4.1 Define requirements for reporting O&M activities

2.4 Dispute Resolution

2.5.1 Define any specific issues for M&V

3. ECM Specific M&V Plan (develop for each ECM)

3.1 Overview of ECM and M&V plan for ECM

3.1.1 Scope of work, location and how cost savings are generated

3.1.2 M&V guideline and M&V Option used

3.1.3 Intent of M&V Plan – what is being verified

3.2 Energy Baseline Development

3.2.1 Describe in general terms how the baseyear energy for this ECM is defined

3.2.2 Variables affecting Baseyear Energy Use

- Variables such as weather, operating hours, set point changes, etc
- Describe how each variable will be quantified, i.e. measurements, monitoring, assumptions, manufacturer data, maintenance logs, engineering resources, etc
- Discuss impact of variables on savings uncertainty

3.2.3 Define key system performance factors characterising the baseyear conditions

- Such as comfort conditions, lighting intensities, temperature set points, etc

3.2.4 Requirements for owner witnessing of measurements if different than whole project data requirements included in Section 2.3

3.2.5 Variables affecting Baseyear Energy

- Parameters to be monitored
- Details of equipment monitored, i.e. location, type, model, quantity, etc
- Desired uncertainty level
- Sampling plan, including details of sample groups and sample sizes
- Duration, frequency, interval, and seasonal or other requirements of measurements
- Personnel, dates, and times of measurements
- Proof of witnessing of measurements (if required)
- Monitoring equipment used and installation requirements
- Certification of calibration/calibration procedures followed
- Expected accuracy of measurements and monitoring equipment
- Quality control procedures used
- Form of data to be collected (xls, csv, etc)
- Results of measurements (attach appendix if necessary
- Completed data collection forms, if used

3.2.5 Data Analysis Performed

- Analysis using results of measurements
- Normalised regressions for weather and other explanatory variables
- Weather data used and source of weather data
- Other explanatory variable data and source of data

3.3 Energy Savings Calculations

3.3.1 Analysis Methodology used

3.3.2 Detail all assumptions and sources of data

3.3.3 Equations used, savings calculation details

- Detail any adjustment that may be required

3.4. Operations and Maintenance Cost Savings

3.4.1 O&M Savings Justification

- Describe how savings are generated
- Detail cost savings calculations

3.4.2 Performance Period O&M Cost Adjustment factors, if used

3.5. Total Annual Savings for ECM

	Electric Energy Savings (kWh)	**Electric Demand Savings (kW)**	**Natural Gas Savings (MJ)**	**Water (kL)**	**Etc …**	**Etc …**	**O&M Cost Savings ($)**	**Annual Energy Cost Savings ($)**	**Total Annual Cost Savings ($)**
Baseline Use									
Post-Install Use:									
Savings:									

Include all applicable fuels and commodities for project, such as: electric energy, electric demand, natural gas, LP gas, fuel oil, coal, water, etc.

3.6 Post-Installation M&V Activities

3.6.1 Describe the intent of post-installation verification activities, including what will be verified

3.6.2 Variables affecting Post-Installation Energy Use

- Variables such as weather, operating hours, set point changes, etc
- Describe how each variable will be quantified, i.e. measurements, monitoring, assumptions, manufacturer data, maintenance logs, engineering resources, etc
- Discuss impact of variables on savings uncertainty

3.6.3 Define key system performance factors characterising the post-installation conditions

- Such as lighting intensities, temperature set points, etc
- Such as comfort conditions, lighting intensities, temperature set points, etc

3.6.4 Requirements for owner witnessing of measurements if different than whole project data requirements included in Section 2.3

3.6.5 Post-Installation Data To Be Collected

- Parameters to be monitored
- Details of equipment monitored, i.e. location, type, model, quantity, etc
- Desired uncertainty level
- Sampling plan, including details of sample groups and sample sizes
- Duration, frequency, interval, and seasonal or other requirements of measurements
- Personnel, dates, and times of measurements
- Monitoring equipment used and installation requirements
- Calibration requirements and procedures
- Expected accuracy of measurements and monitoring equipment
- Quality control procedures used
- Form of data to be collected(xls, csv, etc)
- Completed data collection forms, if used

3.6.6 Data Analysis to be performed and minimum acceptance requirements

3.7 Periodic / Interval Verification Activities for Performance Period

3.7.1 Describe in general terms how the performance period energy use will be determined

3.7.2 Variables affecting Performance Energy Use

- Variables such as weather, operating hours, set point changes, etc
- Describe how each variable will be quantified, i.e. measurements, monitoring, assumptions, manufacturer data, maintenance logs, engineering resources, etc
- Discuss impact of variables on savings uncertainty

3.7.3 Define key system performance factors characterising the performance period conditions

- Such as comfort conditions, lighting intensities, temperature set points, etc

3.7.4 Intent of periodic verification activities – what will be verified

3.7.5 Schedule of periodic verification activities and inspections

3.7.6 Requirements for owner witnessing of measurements if different than whole project data requirements included in Section 2.3

3.7.7 Data to be collected

- Parameters to be monitored
- Details of equipment monitored, i.e. location, type, model, quantity, etc
- Desired uncertainty level
- Sampling plan, including details of sample groups and sample sizes
- Duration, frequency, interval, and seasonal or other requirements of measurements
- Monitoring equipment used and installation requirements
- Calibration requirements and procedures
- Expected accuracy of measurements and monitoring equipment
- Quality control procedures used
- Form of data to be collected(xls, csv, etc)

- Results of measurements (attach appendix if necessary
- Sample data collection forms, if relevant

3.7.8 Data Analysis to be performed and minimum acceptance requirements

3.7.9 O&M Reporting Requirements

- Detail verification activities and reporting responsibilities of owner and ESCO on O&M items.
- Responsibilities for equipment operations
- Responsibilities for performing maintenance
- Responsibilities for performing repairs

APPENDIX 3: M&V OPTIONS TECHNOLOGY-SPECIFIC ECMS

FEMP M&V GUIDELINES Version 2.2 – Section 1 Chapter 2 Section 2.4 – Table 2.3

The selection of an appropriate M&V option (A, B, C, D) and many of the implementation details are largely determined by the retrofit technology that is supposed to generate energy savings. Table 2.3 in the FEMP M&V Guidelines Version 2.2 provides a summary of M&V Methods defined for different specific energy retrofits categorised by option and ECM technology.

Note 1: The FEMP M&V Guidelines Version 2.2 were issued in September 2000 and were consistent with IPMVP 1997. Since that time IPMVP 2001 was issued. The major change affecting the FEMP M&V Guidelines was the change to Option A which no longer allows full stipulation. In May 2002, an update to the FEMP Option A was released, entitled “Detailed Guidelines for FEMP M&V Option A”. The Section numbers for Option A refer to the updated document for Option A. In Section 5 of the updated document, details are provided of the compliance of the FEMP Option A Method Number with IPMVP 2001(and to March 2002 revised edition).

Table A3.1

FEMP Method Number	Section/ Chapter	ECM	Option	Approach
LE-A-01	**Section 5.1**	Lighting efficiency	**A (Note1)**	**No metering (Note 2)**
LE-A-02	**Section 5.1**	Lighting efficiency	**A (Note1)**	Spot metering of fixture wattage
LE-B-01	IV/13	Lighting efficiency	B	Continuous metering of operating hours
LE-B-02	IV/14	Lighting efficiency	B	Continuous metering of lighting circuits
LC-A-01	**Section 5.2**	Lighting controls	**A (Note 1)**	**No metering (Note 3)**
LC-A-02	**Section 5.2**	Lighting controls	**A (Note 1)**	Spot metering of fixture wattages
LC-B-01	IV/15	Lighting controls	B	Continuous metering of operating hours
LC-B-02	IV/16	Lighting controls	B	Continuous metering of lighting circuits
CLM-A-01	**Section 5.3**	Constant load motors	**A (Note 1)**	Spot metering of motor kW

Table A3.1 (continued)

FEMP Method Number	Section/ Chapter	ECM	Option	Approach
CLM-B-01	IV/17	Constant load motors	B	Continuous metering of motor kW
VSD-A-01	**Section 5.4**	Variable speed drive retrofit	**A (Note 1)**	Spot metering of motor kW
VSD-B-01	IV/18	Variable speed drive retrofit	B	Continuous metering of motor kW, speed frequency, or controlling variables
CH-A-01	**Section 5.5**	Chiller retrofit	**A (Note 1)**	**No Metering (Note 3)**
CH-A-02	**Section 5.5**	Chiller retrofit	**A (Note 1)**	Verification of chiller kW/ton
CH-B-01	IV/19	Chiller retrofit	B	Continuous metering of new chiller and cooling load
CH-B-02	IV/19	Chiller retrofit	B	Continuous metering of new chiller and cooling equipment
GVL B-01	IV/20	Generic variable load project	B	Continuous metering of end-use energy use
GVL-C-01	V/22	Generic variable load project	C	Utility bill regression analysis
GVL-C-02	V/23	Generic variable load project	C	Utility bill comparison
GVL-D-01	VI/25	Generic variable load project	D	Calibrated simulation model

Note 2. Section 5 of the updated FEMP Option A Guidelines states that U.S. Federal Agencies can regard Method Number LE-A-01 to be IPMVP-compliant “if fixture powers are taken from a table based on measurements”.

Note 3. Section 5 of the updated FEMP Option A Guidelines states that U.S. Federal Agencies should regard Method Numbers LC-A-01 and CH-A-01 as not being IPMVP-compliant.

FEMP M&V Guideline Boiler Replacement or Improvement

The FEMP M&V Guidelines Version 2.2 do not explicitly discuss methods for boiler replacement or efficiency improvement. The updated “Detailed Guidelines for FEMP Option A” provides guidance on the conditions that have to be satisfied for Option A to be IPMVP-compliant for boiler replacement or improvement.

APPENDIX 4: OPTION C CALCULATION METHODS

"If you compare apples with oranges - you will be confused?"

Background

This Appendix provides guidance on how the savings are determined for the Option C method using regression analysis to create the Baseline Energy in the post-retrofit period using the baseyear energy measurements and the baseyear and post-retrofit non-ECM data.

Figure A4.1 shows a generalised Option C computational method which is as follows

1. A Baseline Model is created from an analysis of the relationship between baseyear energy data and selected baseyear non-ECM factors.
2. The Baseline Energy for the post-retrofit period is estimated by applying the post-retrofit non-ECM conditions to the Baseline Model, for the same baseyear non-ECM factors used to create the Baseline Model,
3. The Reported Savings are the difference between the estimated Baseline Energy values and the actual Post-Retrofit Energy measurements.

The computational methods used to calculate Baseline Energy values use mathematical estimation techniques and algorithms ranging from relatively simple to relatively complex. The quality and credibility of the calculated savings depend mainly on

- selection of and apprtopriate computational method
- the knowledge, skills and experience of those responsible for calculating the savings
- the discipline and transparency of the computational processes
- the handling of uncertainties in data and those inherent in the selected computational process.

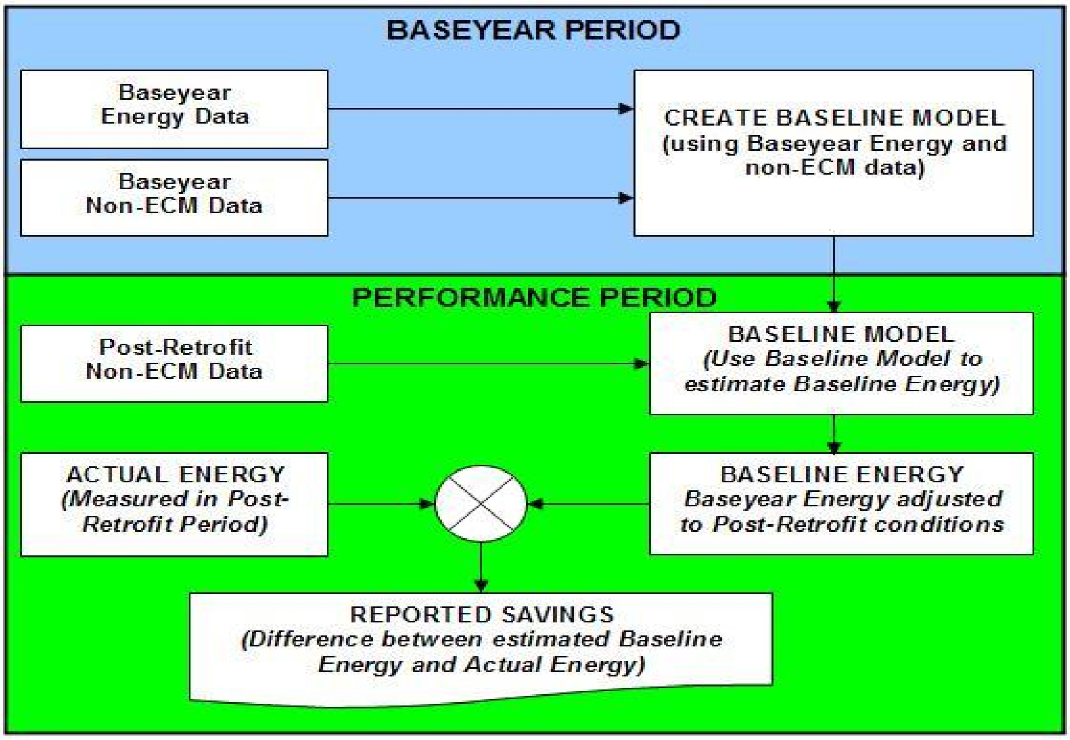


Figure A4.1 Generalised Option C Computational Process

Baseline Model Development

Option C determines the collective savings of all ECMs applied within a measurement boundary for a facility which has energy use for the whole facility measured by a meter. The meter is normally a utility meter which has a continuous historical billing data records and which will continue to be used to measure future energy use.

Because the meter measures the energy use changes caused by all the ECMs as well as changes caused by the influences of non-ECM factors, such as weather, occupancy and production levels, the computational method has to separate out the energy changes caused by ECM from changes caused by non-ECM factors.

As shown in Figure A4.1, the first step in the computational is to develop a valid Baseline Model that represents the predictable influences of identified specific non-ECM factors on the measured baseyear energy of the facility.

The second step is to use the Baseline Model to predict Baseline Energy for the post-retrofit period by applying post-retrofit non-ECM data, for the identified non-ECM factors, to the model.

During development of the Baseline Model the mathematical methods provide assistance in identifying the non-ECM factors – referred to as the explanatory variables of the Baseline Model – that have predictable and statistically valid relationships with the measured baseyear energy data. These same mathematical methods are used to develop forecasting models for many other uses, such as forecasting the demand for ice-cream which is influenced in a predictable way by seasonal factors such as weather.

Multivariate linear regression analysis is the most common method for developing M&V prediction models for Baseline Energy. A typical Baseline prediction model for electricity consumption (kWh) created by regression analysis with four (4) explanatory variables is expressed in the form of a linear equation which calculates the energy consumption based on the number of days and the values of the explanatory variables.

When the energy consumption is influenced by weather, Cooling Degree Days (CDD) and Heating Degree Days (HDD) are used as two of the explanatory variables in the model (refer to Chapter 6 for further explanation of weather severity variables).

The following is an example of a Baseline Model with a “number of days” explanatory variable, two weather severity explanatory variables and an ‘occupancy” explanatory variable.

$$Q(kWh) = B_0 \times \text{Number of Days} + B_1 \times \text{CDDs} + B_2 \times \text{HDDs} + B_3 \times \text{Occupancy}$$

where

- **Q(kWh)** is the predicted energy consumption for a defined reporting period, given the number of days in the period and the values for the other three explanatory variables in the Baseline Model.
- B_0 is the model coefficient (expressed in kWh per day) for daily consumption and “**Number of Days**” is the number of days in the reporting period for which Q(kWH) is being predicted
- B_1 is the model coefficient (expressed in kWh per CDD) for cooling weather severity and “**Cooling Degree Days** (CDD)” is the number of CDDs calculated from weather data for the reporting period.
- B_2 is the model coefficient (expressed in kWh per HDD) for heating weather severity and “**Heating Degree Days** (HDD)” is the number of HDDs calculated from weather data for the reporting period
- B_3 is the model coefficient (expressed in kWh per number of occupants) for occupancy and “**Occupancy**” is the number of occupants for the reporting period.

Baseline model development

A Baseline Model is created as illustrated in Figure A4.2. Regression analysis is used to find statistically valid explanatory variables that influence the energy behaviour of the facility, and to estimate the values of the model coefficients (B_0 to B_3 in the above equation**)**.

The statistical validity of the Baseline Model is determined by a number of standard statistical indicators produced as a part of the regression analysis process. (Refer to Appendix 5.)

The following are the key indicators:

- “Goodness of Fit” is the measure of the overall suitability of the Baseline Model. It is also called the Coefficient of Determination (R^2). The maximum possible value is $R^2 = 1$ when the model fully explains the energy behaviour without any residual error. For an acceptable M&V model **R^2 should be greater than 0.75**.

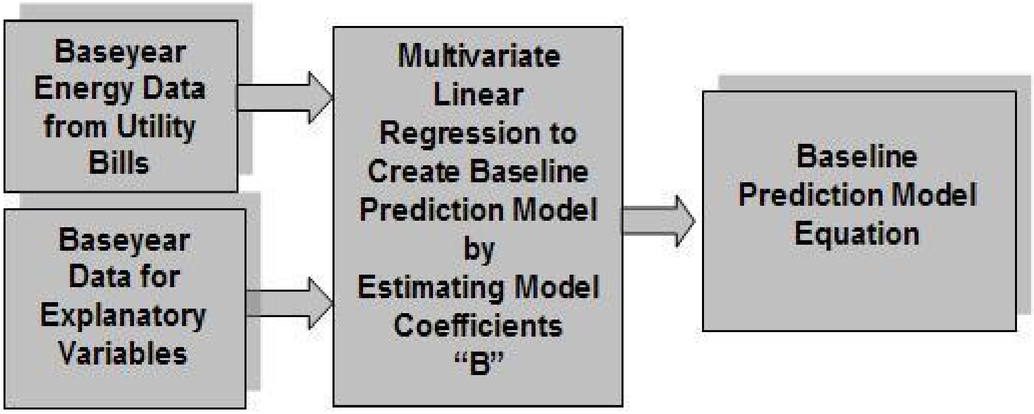


Figure A4.2 Baseline Model creation process

- The T-Statistic is a standard statistical indicator of the significance of the influence of the explanatory variable on the energy behaviour. For an explanatory variable to be included in the model the **absolute value of the T-Statistic for the associated model coefficient should be greater than 2.** T.
- A statistically valid prediction model should be able to re-compute the prediction of the baseyear energy data, using the baseyear data that was used to create the prediction model, with a very small difference between the actual baseyear energy data and the predicted baseyear energy data. The statistical test is known as the "Net Determination Bias" or the "Net Mean Bias". **The Net Determination Bias should be no more than 0.005%**
- The Monthly Mean Error (technical statistical term abbreviation is CV(RMSE)) is a statistical measure of the prediction accuracy of the model**. For energy use and demand the Monthly Mean Error should be less than 25% for energy and 35% for demand, respectively, when 12 months to 60 months of data is used to compute savings.**

If a potential explanatory variable cannot be included in the Baseline Model because it does not have a statistically significant influence then it remains as a potential factor for a Baseline Adjustments (refer to Chapter 5).

The main best practice requirements for developing a statistically valid Baseline Model are (refer to Appendix 5):

- There are at least twelve (12) billing data points available in the baseyear period
- It is preferred than the number of billing data points in the baseyear period are a multiple of 12 so that seasonal or other periodic influences are equally represented
- Billing data points should not be excluded simply to increase the value of R^2
- Billing data points should only be excluded when there is supporting information to substantiate that the value of these points are erroneous e.g. abnormal consumption for one or more billing periods.

Baseline Model creation example

An example of a Baseline Model created using multivariate regression analysis with two weather variables is shown in Figure A4.3.

The Baseline Model is for a utility electricity meter. Twelve months of baseyear data was selected for the regression analysis. The twelve billing data points are shown on the left-hand side of Figure A4.3. The regression analysis established that weather, both Cooling Degree Days (CDD) and Heating Degree Days (HDD), have a statistically significant influence on the baseyear consumption.

<u>"Goodness of Fit" of the Baseline Model</u>

Figure A4.3 shows the visual "goodness of fit" between the actual billing data points (squares) and the line plot of values predicted by the Baseline Model for the baseyear period, using the weather data for the baseyear period. The closeness of the fit between the actual billing data and the recomputed data points shows that the Baseline Model is highly representative of the energy behaviour of the site for the baseyear period. This is confirmed by the statistical indicator of $\mathbf{R^2 = 0.924}$ for the Baseline Model, which is greater than the criteria of $R^2 > 0.75$ (refer to Appendix 5).

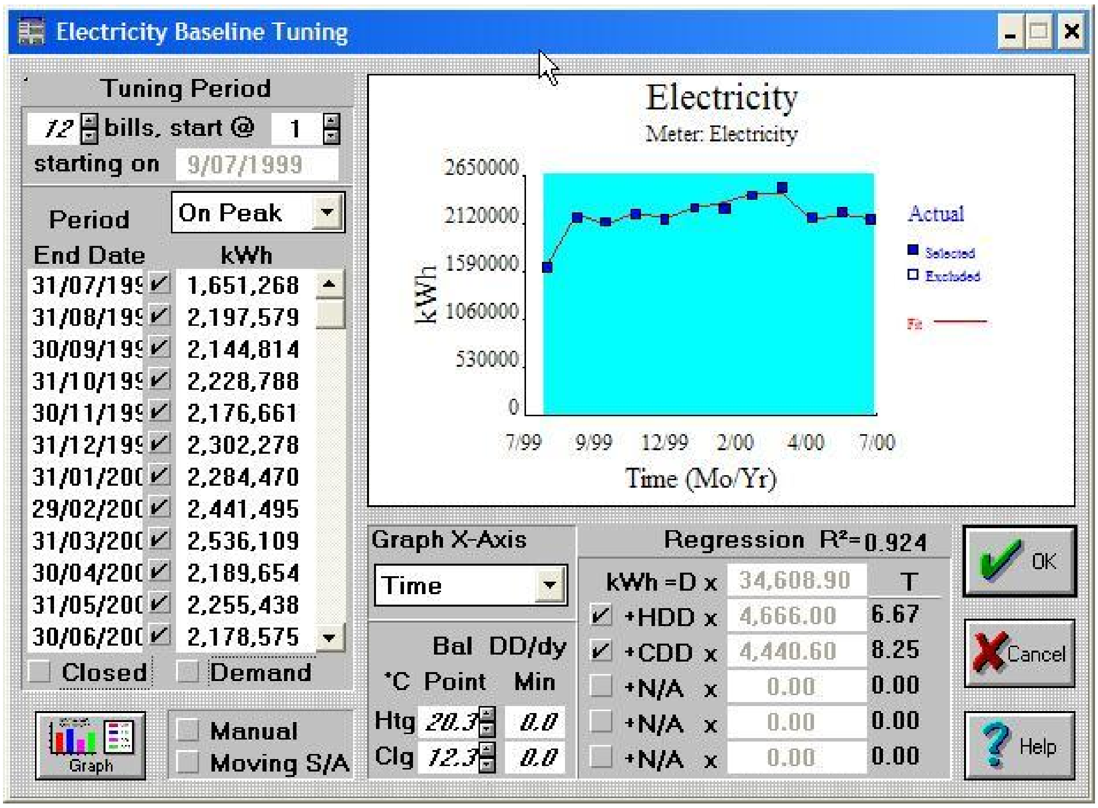


Figure A4.3 Baseline Model Equation and Statistical Indicators

Separate reports (not shown) available from the M&V analysis software showed that **Net Determination Bias is 0.000%,** which is less than the allowable 0.005%. Also the **Monthly Mean Error is 1.6%,** which is less than the allowable 25%.

The credibility of the statistical indicators is supported by the visual "Goodness of Fit" shown by the close fit between the re-computed predicted values (the line plot) and the actual measured energy values (squares)

<u>Statistical Significance of Weather Variables</u>

Heating Degree Days (HDD) and Cooling Degree Days (CDD) are statistically valid explanatory variables for the Baseline Model. (refer to Chapter 6 and Appendix 6 for further explanation of HDDs and CDDs). The T-Statistics for HDD and CDD explanatory variables are shown in Figure 5.3 (lower right hand part). The **T-Statistics for HDD and CDD are 6.67 and 8.25,** respectively. They are statistically significant as they are both greater than + or – 2 (refer to Appendix 5).

<u>Baseline Models are Site-Specific</u>

It is beyond the scope of this Guide to discuss the details of the influence of changing Balance Points for heating and cooling during the creation of the Baseline model. There are separate balance point temperatures for heating and cooling which are specific for each facility/building.

- The "heating balance temperature" is defined as the "outdoor temperature above which no space heating energy is required to be consumed"
- The "cooling balance temperature" is defined as the "outdoor temperature below which no space cooling energy is required

The Heating Balance Point (Htg) and the Cooling Balance Point (Clg) for this specific facility/building are 20.3^{o} C and 12.3^{o} C, respectively.

Changing the balance points changes the statistical significance of the Baseline Model. The challenge when creating a Baseline model with energy influenced by weather is to establish credible and practical Balance Points.

The previously described statistical indicators provide feedback, during the creation of the Baseline Model, to indicate the optimum Balance Points for the specific facility/building.

Baseline Model Equation

The Baseline Model equation for this specific facility is as follows:

Baseline (kWh) = 34,609 x No of Days
+ 4,666 x Heating Degree Days (HDD)
+ 4,441 x Cooling Degree Days (CDD)

This Baseline Model can be interpreted as follows:

- For the baseyear period, the facility had a **"base consumption"** of 34,609 kWh per day. This simply means that irrespective of whether it is a cold day or a hot day, on average, daily base consumption was 34,609 kWh, over the 12-month baseyear period
- For the baseyear period, the additional average energy consumed for heating to maintain the internal comfort conditions during cold days (when the outdoor temperature was colder than the Heating Balance Point of 20.3^{o} C) was 4,666 kWh per HDD.
- For the baseyear period, the additional average energy consumed for cooling to maintain the internal comfort conditions during hot days (when the outdoor temperature was hotter than the Cooling Balance Point of 12.3^{o} C) was 4,441 kWh per HDD.

This Baseline Model equation is an excellent representation of the electricity consumption for this specific facility, as established by the statistical indicators.

The Baseline Model equation can be used to calculate consumption for this facility for any period, for which the appropriate weather data is available. Therefore, it can be used to calculate the "business as usual" Baseline Energy for the post-retrofit period.

Predicting the post-retrofit Baseline Energy

Estimating the post-retrofit Baseline Energy is done by applying the values of the post-retrofit explanatory variables to the Baseline Model, as shown in Figure A4.4.

The accuracy of the predicted post-retrofit Baseline Energy is calculated by using the Monthly Mean Error, which is root mean squared error (RMSE) of the predicted mean. This accuracy measure is provided by standard regression packages as a part of the Baseline model creationand further discussion is beyond the scope of this Guide.

An example of how the Baseline Energy is predicted by the Baseline Model for 30 days in the post-retrofit period is shown by the following calculations. The weather data for the 30 days were used to calculate The number of Heating Degree Days and Cooling Degree Days for the 30 days were calculated from the weather data for the 30 days as 20 and zero,respectively. The following shows the application of "number of days" and the number of HDDs and CDDs for the 30 day period to the Baseline Model.

Baseline (kWh) = 34,609 x 30 + 4,666 x 20
+ 4441 x 0 = 1,131.590 kWh

The result is that the specific facility/site would have consumed 1,131,590 kWh for the 30-day period.

Calculating Baseline Energy for a defined post-retrofit period from the Baseline Model and the post-retrofit conditions is done automatically by M&V software tools. They use the weather data for the post-retrofit period to calculate the number of HDDs and CDDs for the defined period, at the Heating and Cooling Balance Points for the Baseline Model. The Baseline Energy is calculated by applying the number of days and the number of HDDs and CDDs for the defined period to the Baseline Model equation.

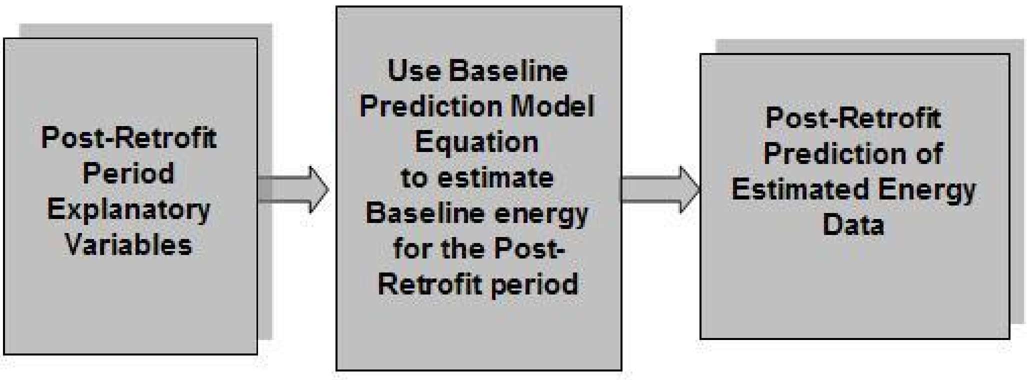


Figure A4.4 Computation Process for Baseline Energy

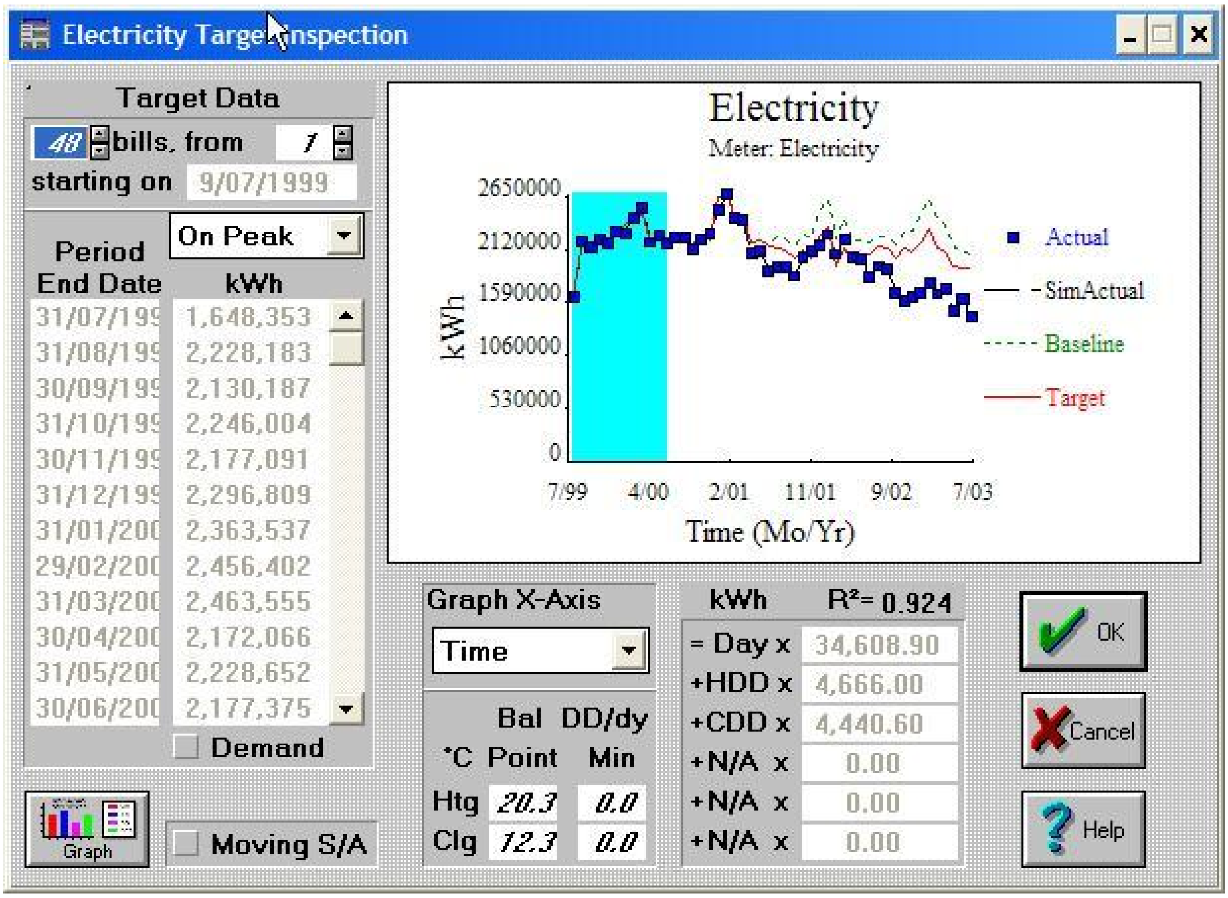


Figure A4.5 Baseline and Actual Energy for Baseyear, Installation and Performance Periods

Baseline Energy and Actual Billed Energy

Figure A4.5 shows plots of the Baseline Energy data (dashed line), calculated by applying the post-retrofit weather data to the Baseline Model equation, and the Actual Billed Energy data (square points) for the following periods

- The baseyear period is highlighted (light blue) and covers the 12-month period of July 1999 to June 2000 (refer to dates and data on the LHS of Figure A4.5). As discussed previously, the actual billing data and the weather data for this period were used to create the Baseline Model equation. The closeness of fit between the actual consumption data points (squares) and the re-computed baseyear energy data (line plot) re-confirms visually that the Baseline Model equation is an excellent representation of the energy behaviour of the site for the baseyear period.
- The period to the immediate right of the baseyear are the Installation Period and the Performance Period. The Actual Billed Energy data points (squares) and the plot of the Baseline Energy (dashed line), for the Installation and Performance Periods are shown.

The dashed line represents the Baseline Energy values calculated from the Baseline Model equation by applying the "number of days" and the number of HDDs and CDDs for the post-retrofit period.

The continuous line, below the dashed Baseline Energy line, represents the "Target" Energy values, which was calculated by subtracting the expected ECM savings from the calculated Baseline Energy values. **The separation of the "dashed" and the "continuous" lines occurs at the start of the Performance Period. The Installation Period extends from the end of the Baseyear Period to the start of the Performance Period.**

The variations in Actual Energy values after the start of the Performance Period can be attributed to the energy reduction caused by the successful performance of the ECM implemented by the contractor during the Installation Period. There would be no savings if the Actual Energy plot was above the Baseline Energy. If the Actual Energy plot is below the Target Energy line, it means that the savings performance of the ECM is better than expected (positive savings), otherwise the ECM is not performing as expected.

Visual inspection of Figure A4.5 shows that the overall savings performance of the ECM is positive (monthly Actual Energy consumption is below the monthly Target Energy consumption), except for a couple of months).

It is normal practice to calculate the savings and to reconcile the achieved savings against the expected/guaranteed savings for each 12 month period in the post-retrofit Performance Period. The monthly savings are calculated by subtracting the monthly Actual Energy from the monthly Baseline Energy. The annual savings are simply the summation of the monthly savings for a 12-month Performance Period.

Further reading – Option C

The IPMVP Volume 1 (March 2002) gives general guidance in Section 3.4.3 on the use of the Option C method. An Option C example is presented in Appendix A of IPMVP Volume 1 (March 2002).

Further procedural and technical details on the best practice for savings determination using Option C are available in

- ASHRAE Guideline 14-2002 Sections 6.1, and Annex D, and
- The FEMP M&V Guidelines Version 2.2 in Sections V

APPENDIX 5: GUIDELINES FOR CREATING AN OPTION C BASELINE MODEL

The Baseline Model Creation Guidelines have been selected from the following sources:

- ASHRAE Guideline 14-2002, Section 5.3.2.1 – Whole Building Prescriptive Path
- Waltz, J.P, "Management , Measurement &Verification of Performance Contracting", Chapter 14, "M&V Software for Option C"
- M&V best practices and experience

The Guidelines presented below have been summarised for the sake of clarity. Technical details of some of the guidelines are not relevant and have not been presented.

The following are a set of practical guidelines for the creation of statistically valid Baseline Models

1. Use of Option C Approach

   The expected savings should exceed 10% of the measured energy use or demand.

2. Baseyear Period

   - *The Baseyear Period should be in multiples of roughly 365 days.*
   - *The end of the Baseyear Period should be as close as possible to the beginning of the Installation Period.*
   - *There should be at least 12 valid billing data points in baseyear period.*

3. Balance Points

   - *Energy, Demand and different TOU categories do not need to have the same balance points.*
   - *The selected balance points should be reasonable and explainable.*

4. Manually Excluded Points

   - *Exclude only if there is a reason such as one-time anomalous points*
   - *Exclude as few points as possible*
   - *R-squared and T-statistic should not be used as sole criteria to decide if a point is "convenient" or not.*
   - *Determine and document why point is anomalous*

5. Statistical Validity Criteria

   - *R-squared must be > 0.75.*
   - *Absolute value of T-statistic for explanatory variables must be >2.*
   - *Absolute value of Mean Bias should be < 0.005% excluding de-selected points.*
   - *The Monthly Mean Error (CVRMSE - Coefficient of Variation of the Root Mean Square of the Error) must be < 25% for energy and <35% for demand when 12 to 60 months of baseyear data are used.*
   - *The baseload constant should not be negative.*
   - *The weather coefficient should not be negative.*
   - *Use "Bill Matching" if the regression is not statistically significant.*

6. Explanatory Variables

   - *When in doubt include fewer variables.*
   - *Variables should be normally distributed.*
   - *Variables should be independent of each other.*
   - *Highs and Lows of a variable should span at least 2 to 1.*

APPENDIX 6: WEATHER-CORRECTED ENERGY PERFORMANCE

Background

The following example illustrates how standard M&V techniques can be used to estimate the magnitude of weather-based error components in a portfolio energy performance reporting program (Refer to Nicolosi, A.P).

The example uses one electricity meter in one building selected from a portfolio of buildings. The selected building and a large number of the other buildings in the portfolio are located in a Capital City in Australia.

The base reference year for the portfolio energy reporting program is 2000/2001 and the current reporting year is 2001/2002. Monthly electricity billing data is available for these two years and daily high and low temperature data is available from the closest Bureau of Meteorology weather station. The summer of the base reference year – 2000/2001 – was abnormally hot and the summer of the reporting year – 2001/2002 – was much cooler. There were concerns that this weather difference could affect the validity and credibility of the energy reduction determination and reporting for the site.

There had been no major energy retrofits during the reporting year and the no material changes to the utilisation, operations and/or maintenance of the building.

First Step

The first step is to compare the monthly electricity consumption data for the two periods as this highlights year-to-year monthly and seasonal differences.

Figure A6.1 shows that there are significant differences in the year-to-year comparison of monthly consumptions, especially for the summer months November to February. There had been no energy retrofits or other changes during the reporting that could account for the significant differences in monthly consumptions.

The reduction in annual consumption for the reporting year relative to the base reference year without any weather correction is 408,003 kWh (25%), calculated as follows:

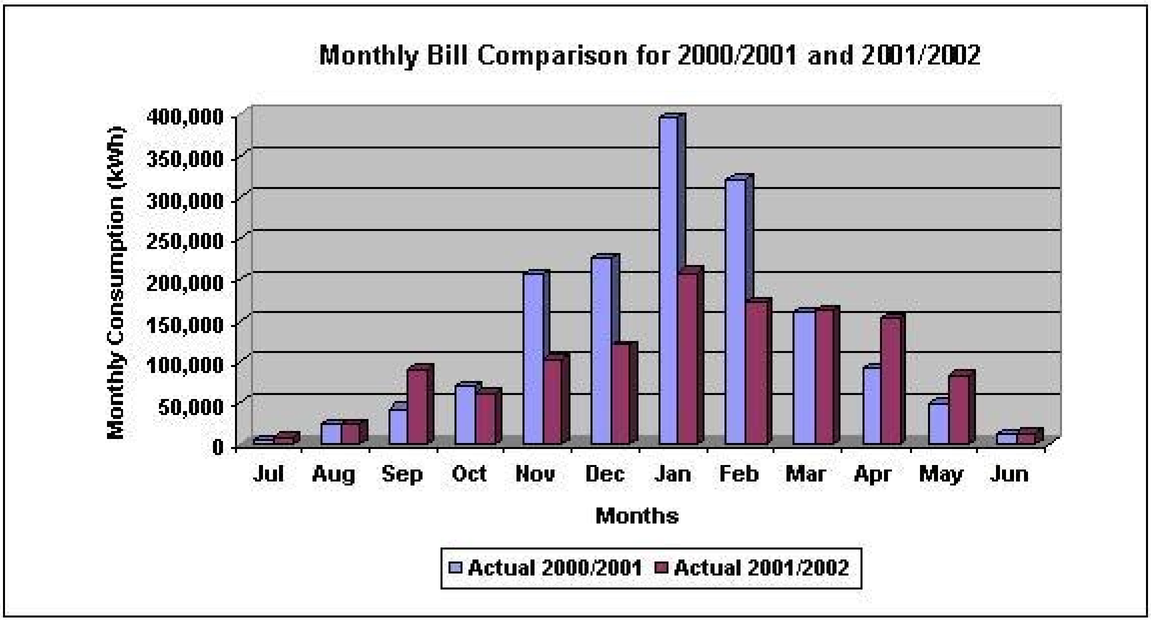


Figure A6.1 Monthly Bill Comparison for 2000/2001 and 2001/2002

Total Annual Consumption for 2000/2001 in kWh	1,605,138
Total Annual Consumption for 2001/2002 in kWh	1,197,135
Consumption Reduction before Weather Correction	408,003

Percentage Reduction relative to Base Reference Year……25%

Second Step

The second step is to examine the variation in weather data - daily high and low temperature - over the two years. It is too difficult to conclude anything from the daily variation of the temperature data.

This is illustrated in Figure A6.2 which shows the high/low temperature data for the first 9 readings (Hi 1 = Highest Temperature Reading and Lo 1 = Lowest Temperature Reading, for the first day of the month) for the first few days in each month for the period July to December 2000.

Third Step

Because the most significant weather differences are for the summer months, the third step is to calculate the monthly Cooling Degree Days (CDD), relative to the standard Balance Point of 18.3°C (refer to Chapter 6), and then to compare the year-to-year monthly differences.

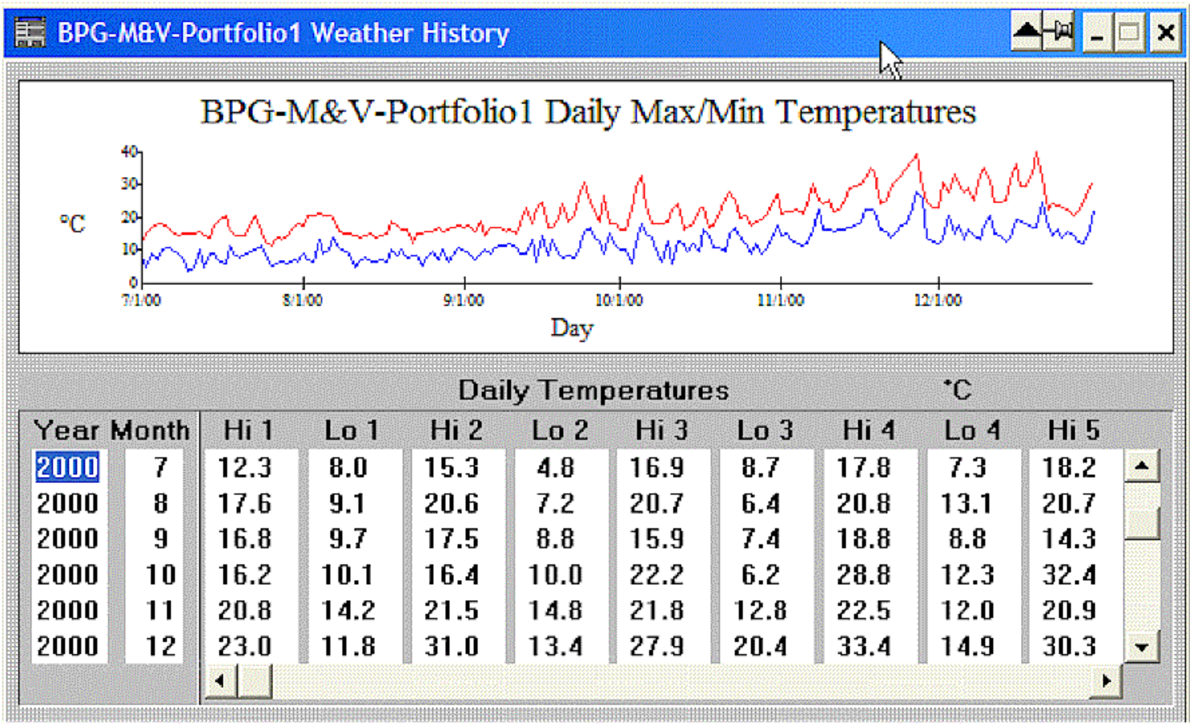
A visual comparison of the year-to-year monthly differences in consumptions (Figure A6.1) and the year-to-year monthly differences in the number of Cooling Degree Days (Figure A6.3) shows that the largest differences in monthly consumptions occurred when there were the largest differences in the monthly number of Cooling Degree Days. As shown below, there is a significant reduction in the Total Annual CDDs in the reporting year relative to the base reference year:

Total Annual CDD for 2000/2001	858
Total Annual CDD for 2001/2002	379
Difference in Annual CDD	479

Percentage Difference relative to Base Reference Year………..56%

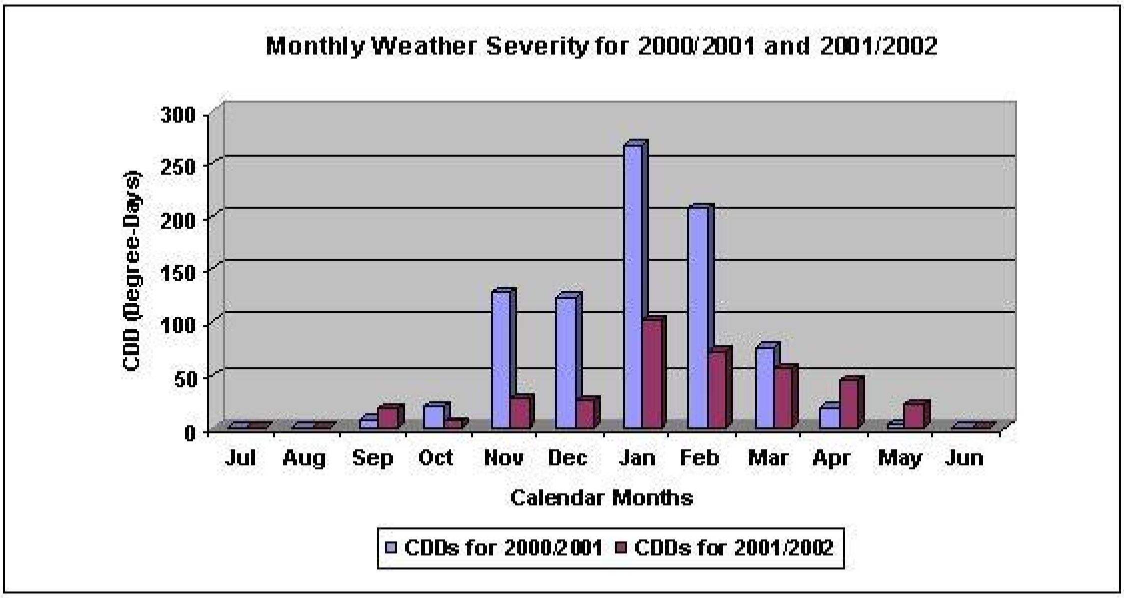
From the above, it is reasonable to conclude that the significant difference of 56% in the annual CDDs could account for a significant proportion or all of the 25% reduction in annual consumption for the reporting year relative to the base reference year.

Figure A6.2 Monthly Bill Comparison for 2000/2001 and 2001/2002



Year	Month	Hi 1	Lo 1	Hi 2	Lo 2	Hi 3	Lo 3	Hi 4	Lo 4	Hi 5
2000	7	12.3	8.0	15.3	4.8	16.9	8.7	17.8	7.3	18.2
2000	8	17.6	9.1	20.6	7.2	20.7	6.4	20.8	13.1	20.7
2000	9	16.8	9.7	17.5	8.8	15.9	7.4	18.8	8.8	14.3
2000	10	16.2	10.1	16.4	10.0	22.2	6.2	28.8	12.3	32.4
2000	11	20.8	14.2	21.5	14.8	21.8	12.8	22.5	12.0	20.9
2000	12	23.0	11.8	31.0	13.4	27.9	20.4	33.4	14.9	30.3

Figure A6.3 Monthly Weather Severity for 2000/2001 and 2001/2002



Fourth Step

The fourth step is to use a Whole-Building Option C savings determination method to find out if a statistically valid Baseline Model can be created that defines the relationship between the monthly consumption and the monthly weather severity for the base reference year. An M&V software tool was used to create the Baseline model for the electricity meter by performing a linear regression between the monthly electricity consumption data and the monthly weather severity for the base reference year of 2000/2001. The results of the linear regression of the 12 billing data points and the daily weather data for the base reference year are presented in Figure A6.4.

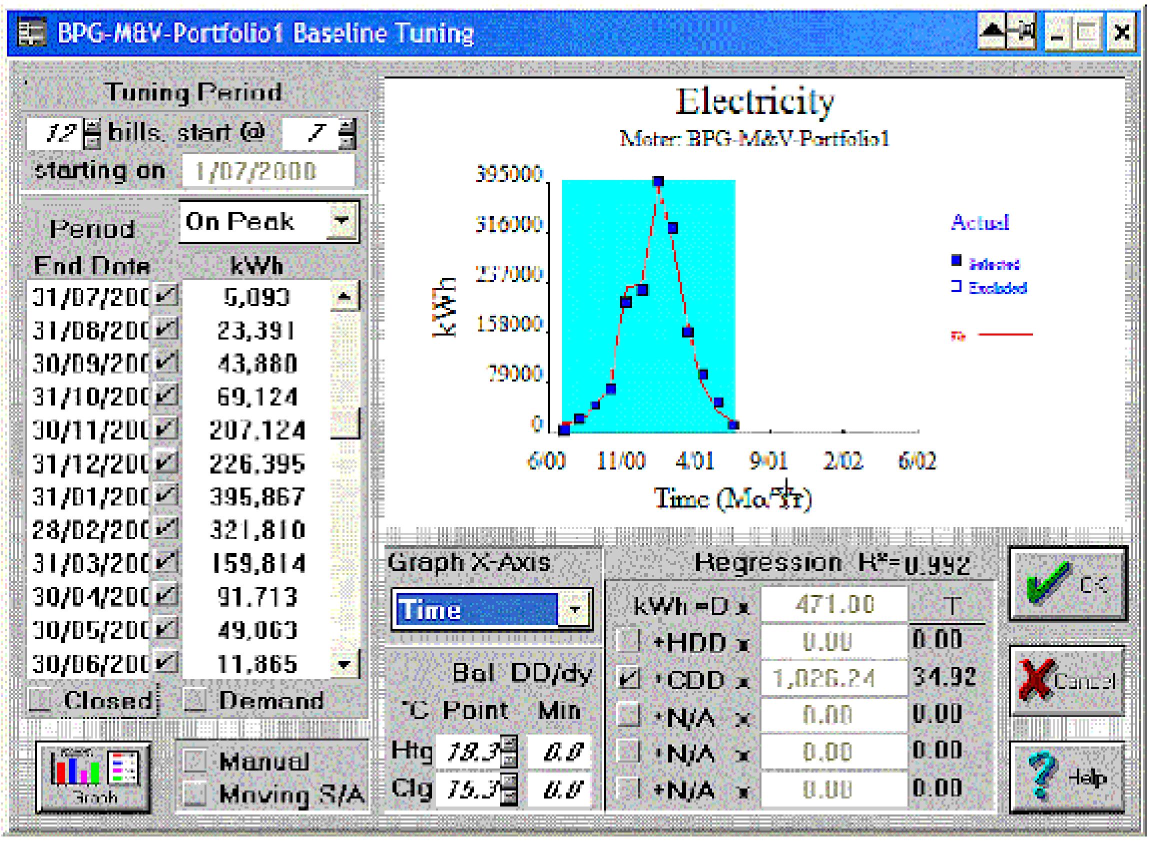


Figure A6.4 Statistical Validity of Baseline Model for Base Reference Year

Figure A6.4 shows the visual "goodness of fit" between the actual billing energy data points (blue squares) and the re-computed energy plot using the Baseline Model (points connecting by red line) for the base reference period. The closeness of the fit between the actual billing data and the recomputed data shows that the Baseline Model is highly representative of the energy behaviour of the site for the base reference period. This is confirmed by the statistical indicator R^2 = 99.2% of the "Goodness of Fit" of the Baseline Model, which is significantly greater than the criteria of R^2 > 75% (refer to Appendix 5).

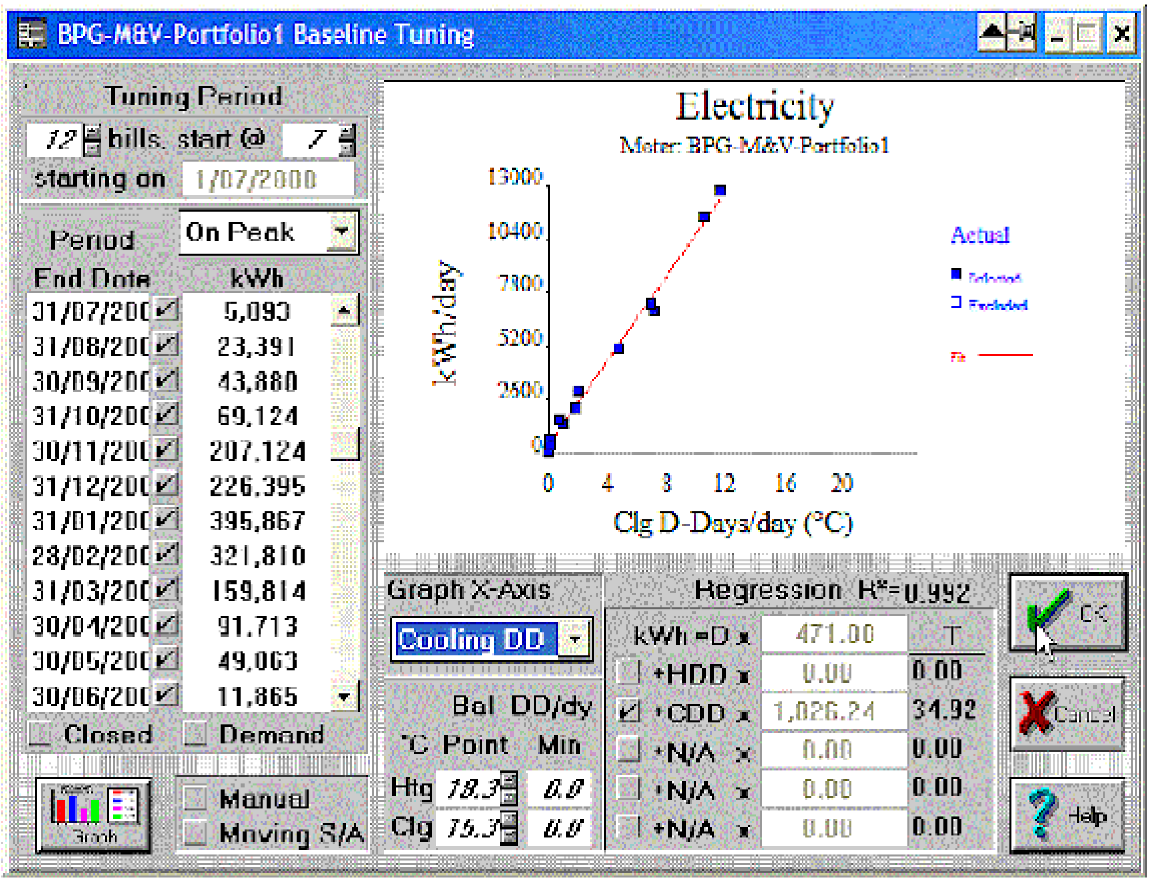
Cooling Degree Days (CDD) is a statistically valid explanatory variable for the Baseline Model at a Cooling Balance Point of 15.3°C. As shown in Figure A7.4 (on the lower right hand part of the diagram) the T-Statistic is 34.92 for CDD. The criteria for retaining an explanatory variable in a Baseline Model is that the T-Statistic of an explanatory variable has to be greater than + or - minus 2 and that the larger the T-Statistic the better the explanatory variable.

The very strong linear relationship between monthly consumption and monthly CDDs is further illustrated visually in Figure A6.5. The very close positioning of actual billing data points along the red straight line shows that Cooling Degree Days is an excellent explanatory variable of the monthly variation in consumption. This simply means that monthly consumption increases and decreases in a consistent and predictable way in response to monthly increases and decreases in the number of Cooling Degree Days.

The overall relationship between monthly consumption and the number of Cooling Degree Days is represented by the following Baseline Model equation:

Baseline (kWh) = 471.08 x No of Days + 1,026.24 x No of CDDs

Figure A6.5 Relationship Between Consumption and Cooling Degree Days



The interpretation of the Baseline Model equation is that during the base reference year period, the base daily consumption for this meter was 471.08 kWh per day and that the monthly consumption variation caused by the weather variation was 1,026.24 kWh/CDD.

The model is statistically valid (refer to Chapter 4 and Appendix 5). The last two indicators are not shown in the diagram above and are available in separate reports.

- The Goodness of Fit, R^2 = 99.2%. This is greater than 75%.
- The T-Statistic for CDD = 34.92. This is greater than + or – 2.
- The Net Mean Bias = 0.1%. This is slightly than 0.005% but is acceptable for this application given that the required accuracy for an energy reduction reporting program normally would not be as stringent as for an energy savings program with financial guarantees. The explanation of the cause of this very small bias in the Baseline Model is beyond the scope of this Guide.
- The Monthly Mean Error = + or – 8.8%. This should be not greater than + or – 25%.

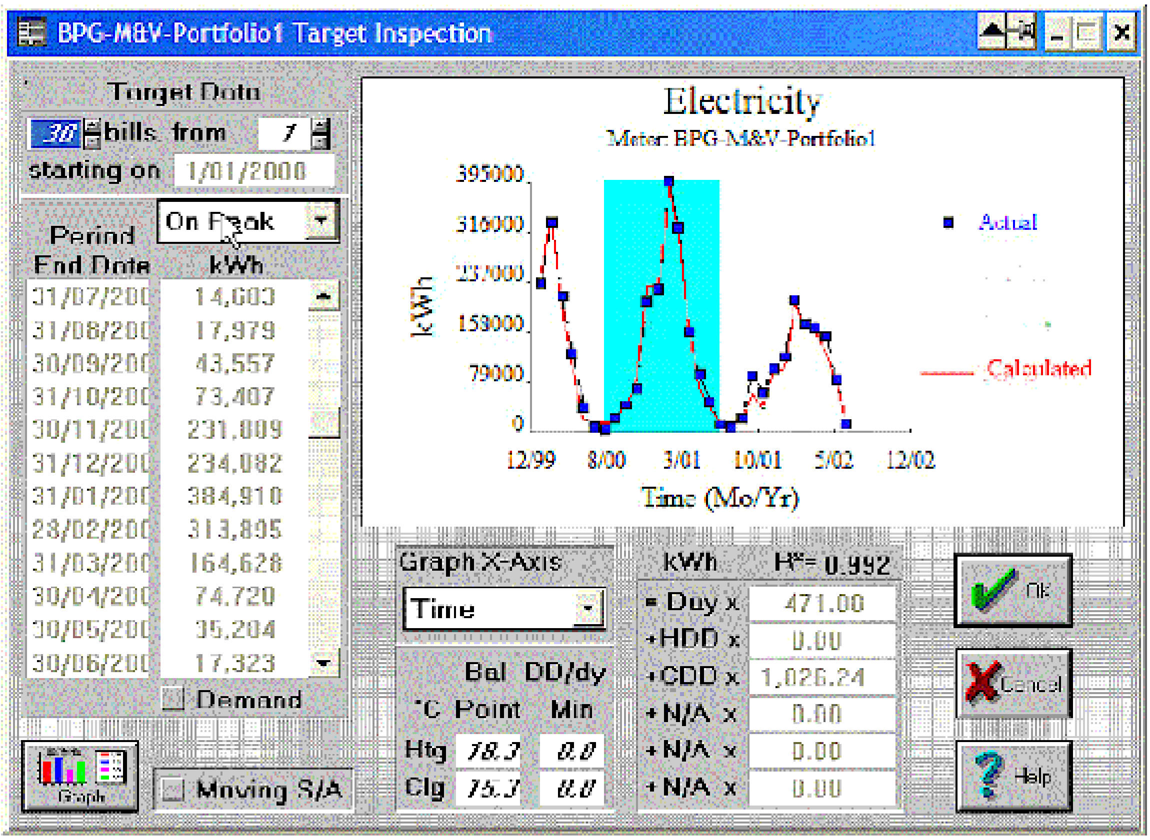
Fifth Step

The fifth step is to use the Baseline model equation to estimate Baseline Energy for the reporting year, representing "business as usual" energy - the energy that would have been consumed if the weather in the base reference year had been the same as the weather in the reporting year.

Calculating monthly Baseline energy is done automatically by M&V software tools. The software tool calculates the number of CDDs for each month, at the Cooling Balance Point of 15.3°C for this site-specific Baseline Model, from the daily high and low temperature data for the reporting year. It applies the number of days and the number of CDDs for each month into the Baseline Model equation. The results of these calculations are presented visually in Figure A6.6.

The diagram shows the plots of actual billing consumption data and calculated consumption data, using the Baseline Model equation, for the (1) base reference year period – shaded light blue area (2) the period before the base refernce year and the (3) reporting year.

Figure A6.6 Comparison of Actual Billing Data and Calculated Data using the Baseline Model



- **Base Reference Year Period**: This shows the same data as in Figure A7.4. The base reference year period (the M&V baseyear period) is highlighted in light blue.The actual billing data and the weather data for this period were used to create the Baseline Model equation. As described previously, the closeness of fit between the consumption data points (shown as dark blue squares) and the re-computed baseyear consumption data (shown by the red line) shows that the Baseline Model equation is an excellent representation of the energy behaviour of the site for the base reference year.
- **Before Base Reference Year Period**: The period to the left of the baseyear period is not important for the energy reduction determination processes. However, the closeness of the fit between the billing data and the calculated data for this period shows that the Baseline Model equation is also an excellent representation of the energy behaviour for the period before the base reference year.
- **Reporting Year:** The period to the right of the base reference year is the reporting period. There are twelve (12) monthly billing consumption data points (shown by the blue squares). The red line is the plot of the Baseline Energy for the reporting period, which is calculated by applying the weather data for the reporting period to the Baseline Model equation.

The Baseline Energy shown for the reporting period is the baseyear consumption weather-corrected to the weather conditions in the reporting period. It is the consumption that would have occurred in the base reference year if the weather in the base reference year had been the same as the weather in the reporting period. A visual comparison shows that the actual monthly consumption for the reporting period is practically the same as the Baseline Energy for the reporting period.

The weather-corrected energy reduction for the reporting period is calculated by subtracting the Actual Energy from the Baseline Energy.

The reduction in consumption for the reporting year relative to the weather-corrected base reference year consumption is as follows:

Sixth Step

The sixth step is to report the following"

"The weather-corrected consumption for this meter for the reporting year of 2001/2002 has increased by 118,000 kWh (11%) relative to the annual base reference year consumption in 2000/2001."

Note that without weather correction, the 2001/02 annual consumption is 408,000 kWh (25%) less than the 200/2001 annual consumption for the base reference year with no weather correction.

This example shows the potential for error in an energy performance reporting process by not weather-correcting the annual consumption of the base reference year before calculating the energy change (positive or negative) for the reporting period.

Baseline Adjustments

In general, routine adjustments for other predictable influence factors and/or Baseline Adjustments for unpredictable changes to buildings may be required. However, the most common adjustment that should be made is weather correction.

The decision of whether to expend the time, effort and money on more extensive adjustments depends on the purpose, required accuracy, required confidence level and the cost-benefit of taking action.

Total Weather-Corrected Annual Baseline Energy for 2001/2002 in kWh	1,079,412
Total Actual Annual Consumption for 2001/2002 in kWh	1,197,135
Annual Consumption Increase After Weather Correction	117,723
Percentage Increase relative to Weather-Corrected Baseline	**10.91%**