Measurement and Verification Operational Guide

Suggested M&V Planning Process

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1 Your guide to successful M&V projects

The Measurement and Verification (M&V) Operational Guide has been developed to help **M&V practitioners, business energy savings project managers, government energy efficiency program managers and policy makers** translate M&V theory into successful M&V projects.

By following this guide you will be implementing the International Performance Measurement and Verification Protocol (IPMVP) a typical M&V process. Practical tips, tools and scenario examples are provided to assist with decision making, planning, measuring, analysing and reporting outcomes.

But what is M&V exactly?

M&V is the process of using measurement to reliably determine actual savings for energy, demand, cost and greenhouse gases within a site by an **Energy Conservation Measure** (ECM). Measurements are used to verify savings, rather than applying deemed savings or theoretical engineering calculations, which are based on previous studies, manufacturer-provided information or other indirect data. Savings are determined by comparing post-retrofit performance against a 'business as usual' forecast.

Across Australia the use of M&V has been growing, driven by business and as a requirement in government funding and financing programs. M&V enables:

- calculation of savings for projects that have high uncertainty or highly variable characteristics
- verification of installed performance against manufacturer claims
- a verified result which can be stated with confidence and can prove return on investment
- demonstration of performance where a financial incentive or penalty is involved
- effective management of energy costs
- the building of robust business cases to promote successful outcomes

In essence, Measurement and Verification is intended to answer the question, "how can I be sure I'm really saving money?[1]"

1.1 Using the M&V Operational Guide

The M&V Operational Guide is structured in three main parts; Process, Planning and Applications.

Process Guide: The *Process Guide* provides guidance that is common across all M&V projects. Practitioners new to M&V should start with the *Process Guide* to gain an understanding of M&V theory, principles, terminology and the overall process.

Planning Guide: The Planning Guide is designed to assist both new and experienced practitioners to develop a robust M&V Plan for your energy savings project, using a step-by-step process for designing a M&V project. A Microsoft Excel tool is also available to assist practitioners to capture the key components for a successful M&V Plan.

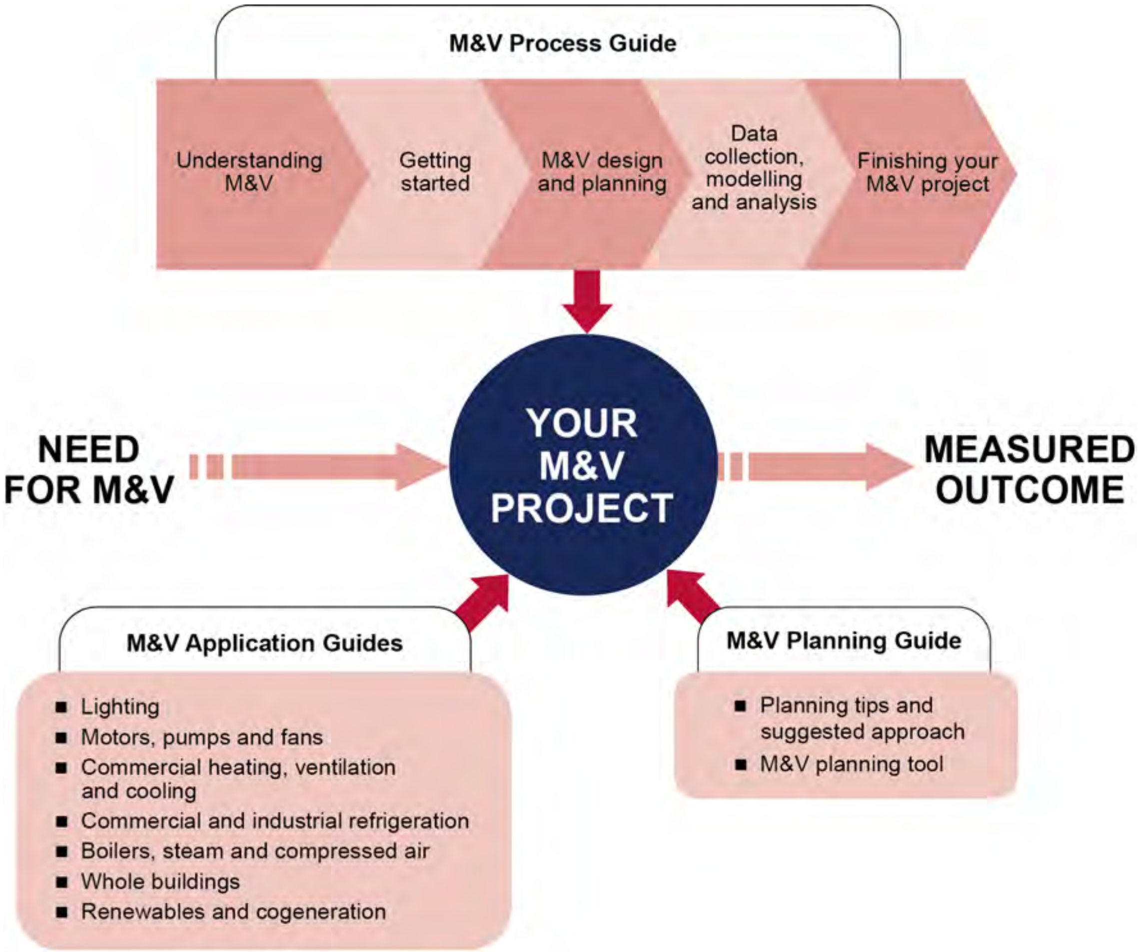
Applications Guides: Seven separate application-specific guides provide new and experienced M&V practitioners with advice, considerations and examples for technologies found in typical commercial and industrial sites. The Applications Guides should be used in conjunction with the Planning Guide to understand application-specific considerations and design choices.

[1] Source: www.energymanagementworld.org

Application Guides are available for:

- Lighting
- Motors, pumps and fans
- Commercial heating, ventilation and cooling
- Commercial and industrial refrigeration
- Boilers, steam and compressed air
- Whole buildings
- Renewables and cogeneration

Figure 1: M&V Operational Guide structure



1.2 The Planning Guide (this guide)

The *Planning Guide* focuses on design and planning for M&V projects. This guide provides a step-by-step approach for designing your M&V project and determining the key elements of your M&V Plan.

1.3 M&V Excel planning tool

A M&V planning tool has been developed in conjunction with this guide to assist M&V planners incorporate the various design elements. The template is presented in a spreadsheet for ease of calculations, with the following contents:

Table 1: M&V Excel planning tool contents

Worksheet Tab	Purpose
ECM Project Background	To capture details for the site and ECM, including the estimated project benefits, implementation plan and key stakeholders
M&V Requirements	To capture the M&V requirements key considerations, desired outcomes and success criteria, as well as the M&V project details.
M&V Design	To capture the essential elements of the M&V Plan. This includes preferred M&V Option, measurement boundary definition, details of key parameters, and process information relating to conducting measurements, calculating saving and uncertainty.
M&V Budget	To prepare a project budget, based on the tasks, resources, equipment and other needs. The final figure is measured against the ECM project costs and savings as a sanity check.
M&V Tasks	To capture the step-by-step list of tasks, and allocation of resources
M&V Timing	A Gantt Chart based timeline, where tasks are given a start and completion date, so that the overall project timeline can be developed.

2 Introduction

2.1 Why prepare a M&V plan?

A well-defined and implemented M&V plan provides the basis for documenting performance in a transparent manner that can be subject to independent, third party verification. A good M&V plan balances the savings uncertainty associated with energy improvement projects against the cost to execute the plan.

Spending the time on M&V design and developing a M&V plan will enable you to:

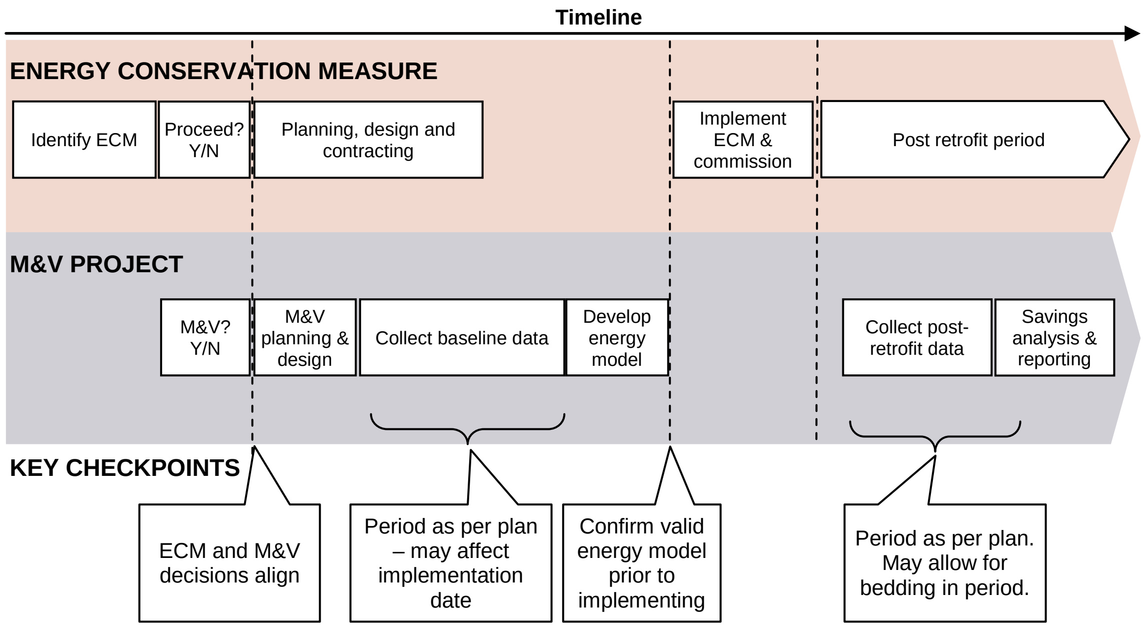
- Map out the M&V project from start to finish
- Estimate the project's requirements in key areas such as cost, timing, and resources
- Evaluate the available M&V approaches and options available to:
  - Identify the most appropriate and least cost path to get the results you need
  - Develop contingencies in the event your primary course of action is not successful
- Understand data collection and analysis needs, and identify gaps to be addressed.
- Document the results of your planning which can be shared as part of a savings agreement or business case, or be available for audit and verification

2.2 Prepare early!

As noted in the *Process Guide* and Figure 2 below, M&V projects are conducted in parallel with the implementation project for their corresponding ECM.

In contrast to the ECM project, most M&V projects are primarily concerned with the equipment, energy system or site as it exists now. Our key requirement is to forecast 'business as usual' energy use using an energy model, which is based on data to be collected and analysed during the baseline period.

Figure 2: ECM and M&V lifecycle timing



As Figure 2 highlights, these tasks occur *before* an ECM is implemented. Once an ECM has been approved and scheduled for implementation we are presented with a finite window of time in which to collect and analyse the data we need. In most cases, once the ECM project has been implemented our ability to collect baseline data is lost forever (e.g. due to retrofits, etc).

In some cases, particularly with M&V Options C and D, there may be the ability to develop and implement a M&V plan *after* the ECM has been implemented, however it can only be based on data that is available.

Formal M&V planning will inform design choices that fit with the ECM implementation time line and maximise the time available for baseline development.

With early planning we should already be in a position to be able to forecast energy use by the time we implement the ECM. Effective planning also provides time to rectify any gaps or deficiencies that have arisen.

Key considerations for developing effective M&V plans include:

Table 2: Effective versus poor M&V plans

	Effective plans	**Poor plans**
Length	Suited to the scope and complexity of the project. Includes diagrams and photographs to enhance description of key elements where beneficial.	Too short (or none at all!) – suitable insufficient explanations for critical elements or not enough detail to explicitly state the project Too long – overly excessive descriptions of each task/step or including content that is not relevant.
Content	Incorporates the required elements listed in Table 4	Incomplete - does not cover all the key elements. For example if there is no plan regarding how energy savings will be converted into cost avoidance (i.e. energy prices), then readers may be wondering how this will occur.
Audience	Can be read and understood by someone who is not directly involved in the project	Does not consider the audience. This is particularly important where multiple stakeholders are involved and/or the M&V plan forms part of a larger business case.
Approach	The intended approach is outlined, including the decision made for each element (e.g. key parameters, measurement boundary). Assumptions, limitations and gaps are articulated. Readers should be able to visualise the approach and elements.	The approach lacks detail, clarity, or does not align with M&V practices. Descriptions of the key elements are not sufficient (e.g. measurement boundary is not sufficiently defined).
Language	Use direct and concise language whilst ensuring it is easy to understand.	Too technical, without explanation Too vague

	Effective plans	Poor plans
Timing	Prepared early to maximise time for activities prior to implementing ECM and addressing gaps. The M&V plan is delivered early enough to influence the ECM implementation plan Some elements of the plan will be generic to many sites and projects and can be reused if available, whilst others are particular to the site and ECM.	Too late – little time is left for implementing the plan prior to ECM implementation, or it is written after the fact to fit available data. The baseline measurement period is shorter than needed and results in a poor energy model.

2.3 Contents of a M&V plan

Like any project, success depends on careful planning. M&V plans come in all shapes and sizes and reflect the following:

- complexity of the site and project
- underlying purpose of M&V (e.g. funding assistance, energy performance contract)
- explanations required for management sign-off
- the size of the available savings and available M&V budget
- audit and verification needs

M&V planning covers the following areas:

Table 3: M&V planning areas and considerations

Area	Why is this important?
People	To ensure key stakeholders are known and appropriate people are involved
Timing	To integrate M&V within the overall project implementation timeline, rather than considering M&V as an afterthought. To ensure that the baseline period and conditions are known and evaluated and that adequate baseline data is collected in order to accurately measure, rather than estimate the project benefits
Resources	To determine the people and equipment needs and forecast when required.
Cost	To understand the anticipated M&V costs so that agreement and funding can be obtained. To facilitate a cost/benefit analysis to determine the level of M&V that should be conducted, if at all.

Area	Why is this important?
Approach and Process	To methodically evaluate the project being considered and develop a suitable baseline from which savings can be claimed. To enable the various M&V approaches to be considered and evaluated so that the preferred approach can be adopted. To define a suitable physical boundary within which the project will be implemented, which will be used as the reference point for ensuring like-for-like comparison. To identify the variables that affect energy use so that the appropriate data types can be measured. To provide a well thought out and documented methodology for manipulating data to calculate savings.
Outcomes	To ensure that the aims and desired outcomes from each stakeholder are known and incorporated into the planned approach. To provide a written document that can form the basis of a savings agreement or guarantee.
Audit and verification	To provide a documented methodology based on an international standard that will support audit and verification

A complete M&V plan should include the following key components:

Table 4: Recommended M&V plan table of contents

Element	Description
Project description	Site and the project details including information about the size and nature of the project, how it will affect site energy usage and demand, implementation plan, key contacts, etc.
M&V project team and manager	List the project team with roles and responsibilities, and contact details including the nominated project manager.
Budget and resources	The agreed M&V budget including the resources required and associated costs covering initial set up costs and ongoing costs throughout the post-retrofit reporting period.
Chosen M&V Option	Nominate the chosen approach for determining savings. Under the IPMVP, this will be a choice between the four available options, A, B, C and D.
Measurement boundary	Describe using words and/or diagrams the chosen measurement boundary. The boundary may be as narrow as a single piece of equipment or as broad as the total energy use across one or more buildings.
Baseline and post-retrofit measurement periods & key dates	Describe the measurement periods for baseline and post-retrofit listing the start and end dates. Where data is available include the baseline energy data from within the measurement boundary. This data may be available from a completed energy audit or feasibility study.

Element	Description
Operating cycle	Describe the operating cycle of the savings that are expected to be achieved and whether or not the measurement period will cover a full cycle. If the measurement period does not cover a full operating cycle, explain how this will be addressed by stipulating or using standard or normalised data sets e.g. standard 10-year average weather file.
Baseline conditions	Describe any baseline conditions and variables that do not include independent variables. These will be factors that are more static in nature, such as internal comfort conditions or lighting levels within a commercial building, or production shifts and details of product line set points in an industrial or manufacturing context. List any conditions that fall short of required conditions, such as low lighting levels or inadequate air flow.
Key measurement parameter(s)	List the key parameters that will be measured, including the data source, and type and frequency of measurement.
Estimated parameter(s) and justification for estimates	List additional parameters that will be estimated. For each, describe the data source, type and frequency of data, and provide a justification for the estimate.
Independent variables and the basis for adjustments	List all independent variables that have been identified as having an effect on baseline energy use. For each, describe the data source, type and frequency of data, and provide a description of how they will be used to adjust the baseline data for the post-retrofit period.
'Interactive effects'	Describe any interactive effects that have been identified where the implementation of the project will have effects on energy use outside the boundary.
Additionality	If multiple projects are planned for implementation and additionality is an issue, describe the approach that will be used to manage additionality.
Methods for collecting data, equipment requirements and metering specifications	Describe the process to be used for collecting measurements, including type, specification and placement of measurement equipment where known. Where Option D has been used, this should describe the modelling software that is used, and all inputs and outputs.
Analysis procedure for calculating results & uncertainty	Specify the data analysis process to be used, and list all significant calculations and assumptions. Where Option D is used, this should describe how the energy model is to be calibrated using measured data.
Energy prices for cost savings calculations	Specify the overall approach and specific cost rates that will be used for calculating energy and demand cost savings, noting any mechanisms for future adjustment.
Expected uncertainty	The expected uncertainty of the energy savings results which will include precision and confidence.
Report format	Specify how results will be reported with a sample output.

Element	Description
Quality assurance	Nominate quality assurance procedures that will be used within the data collection, and preparation of analysis and reports. This may include: Measurement system commissioning Measurement equipment re-calibration frequency Reviewing measured data to spot gaps or out of range conditions Identifying qualified personnel to review draft reports
Ongoing monitoring and periodic inspections	Assign responsibilities for reporting and recording the energy data, independent variables and static factors within the measurement boundary during the reporting period.
Adherence with international protocols	IPMVP Adherent plans also include the following details: ▪ Identifies the person responsible for approving the site-specific M&V plan and for ensuring that the plan is followed for the duration of the reporting period ▪ Clearly state the date of publication or the version number of the IPMVP edition and volume being followed ▪ Terminology that is consistent with the cited IPMVP edition ▪ All required M&V plan elements ▪ Is approved by all parties interested in adherence with IPMVP ▪ Is consistent with the principles of M&V

3 Preparing your M&V project plan

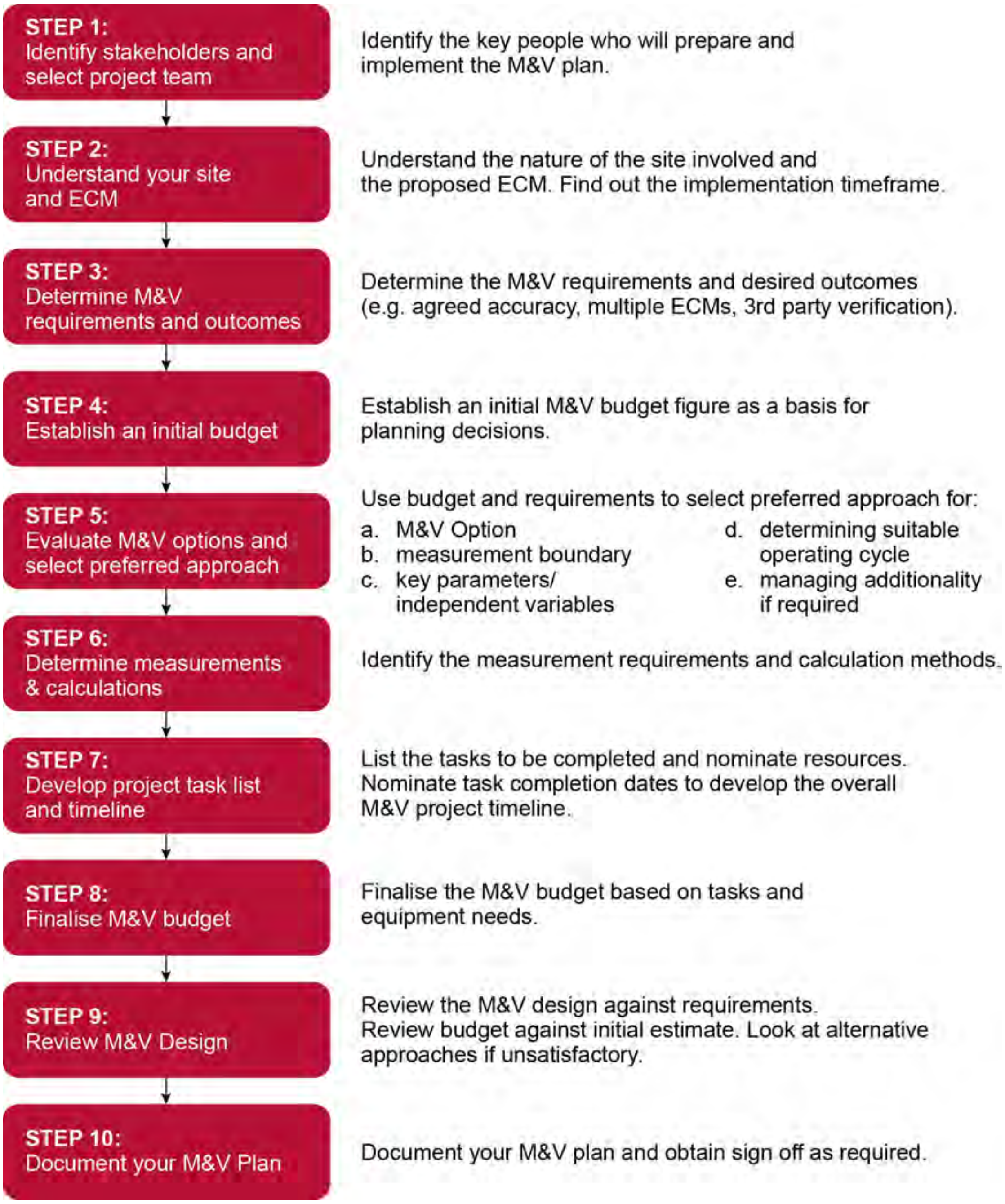
To design an effective M&V plan, we need to understand:

- the nature of the project being implemented
- basic approach and design for conducting M&V
- elements of a robust M&V plan, including tasks, resources, timing and cost; and
- desired outcomes and limitations (e.g. budget).

3.1 Suggested M&V planning process

The suggested M&V planning process listed in Figure 3 below can be used as a basis for developing a M&V plan. A full description of this process is provided in the following sections.

Figure 3: Suggested M&V planning process



3.2 Identify stakeholders and select project team

Step 1

The first step in planning is to identify the people who should be involved in the M&V process. This will include people in the following areas:

- site and corporate stakeholders (site management, production/operations, OH&S and risk, finance, maintenance, environment)
- ECM implementers / contractors
- M&V practitioners

Where M&V is being conducted for a specific purpose, the following stakeholders may also be required:

- Financiers
- Program officers
- Auditors
- ECM designers

Once the stakeholders are known, confirm their role and involvement in the M&V exercise, which may be active or passive.

Select the project manager responsible for coordinating the M&V exercise and preparing the M&V plan.

Note that the nominated project team for conducting M&V will most likely be different from the project team implementing the ECM.

Outcomes from this step

1. Identified key stakeholders
2. Nominated M&V project team and project manager

3.3 Understand your site and ECMs

Step 2

To enable effective planning, it is important to gain an understanding of the site and the proposed ECM(s), as this may affect M&V design decisions including budget, resources, timing, equipment requirements, as well as the physical issues such as access and safety.

From a site perspective, it is important to have a general understanding about the nature of the site. Issues to consider include:

- site overview (energy systems, functional areas)
- access to site and equipment (e.g. remote site, keys, security)
- operation schedules (24/7, weekday, shift)
- maintenance schedules
- safety (heights, chemicals, heat, noise, respiration, exposure to elements, confined spaces, vehicles and traffic) and site induction requirements
- energy types, supply points and available metering/sub metering
- Existing control and data capture systems including Supervisory Control and Data Acquisition (SCADA) systems, Distributed Control Systems (DCS), or Building Management Systems (BMS or BMCS)
- historical energy consumption patterns
- criticality of energy supply to equipment (e.g. IT servers)

Examples of sites where special consideration may be required include prisons, schools, hospitals, and defence sites.

Information can be obtained from site contacts. Access to site diagrams and historical energy use data can be useful. Additional information can also be obtained from energy audit reports where available. If insufficient information is available, then a site visit may be required.

From an ECM perspective is it important to understand the ECM itself, how it affects the site, and the proposed implementation plan. This information will directly affect decision making regarding the available M&V options, timing, and costs to collect data.

Questions to consider

- What is the nature of the ECM and how will it affect the site?
- What is the size of the anticipated savings? How does this relate to the overall site usage?
- Will the ECM affect a single system or affect the site in general?
- Will the ECM affect primary or ancillary operations/equipment?
- Is the ECM linked to a single functional area, or spread throughout the site?
- What assumptions have been made in determining energy consumption and ECM savings?
- Will the ECM result in reduced energy use or demonstrate benefits in other ways, such as increased productivity or throughput?
- What monitoring equipment is there now?
- What is the implementation plan and timing?
- Can the proposed M&V data collection points be sourced from or be built into existing site control systems?

This information can be sourced from an energy audit report where available, and supplemented by discussions with the auditor. Photographs, diagram and plans will assist. Where implementation planning has commenced, the ECM implementer / contractor will be a valuable source of information, especially regarding implementation timing.

Suggested approach

1. Obtain and review reports (e.g. energy audit) and calculations that describe the ECM and estimate the savings. Note any assumptions that have been made.
2. Find out additional background details about the site and where the planned ECM will be implemented. Information can be obtained from site key contacts, the energy auditor or the ECM implementer.
3. Follow up with a site inspection if necessary.

Outcomes from this step

1. Detailed description of the site and ECM
2. List of potential issues that may affect M&V planning
3. ECM implementation dates and milestones

3.4 Determine M&V requirements and outcomes

Step 3

Step three involves determining the M&V requirements and desired outcomes. This is derived from the initial drivers that have identified the need for M&V of the proposed ECM.

Questions to consider:

- What is the purpose/driver for conducting M&V?
- Is M&V a 'need to know' or 'nice to have'?
- Is this an internal or external requirement?
- What is the desired outcome?
- What is an acceptable level of uncertainty (precision and confidence)?
- Should savings be expressed based on 'Actual' or 'Normalised' conditions?
- What is an accepted minimum time period for validity of savings?
- Is 'once off' or ongoing M&V required?
- Will the results be used to support any program, funding or contract requirements?
- What approach and unit prices will be used to calculate cost savings?

These questions will inform the M&V designer regarding:

- overall expectation
- M&V Option
- length of measurement
- extrapolation
- cost vs. accuracy
- formal vs. informal reporting
- seeking agreement/signoff from stakeholders on methods/assumptions

Outcomes from this step

1. Details regarding the purpose for conducting M&V
2. Required and desired outcomes which may influence M&V design

3.5 Establish and initial budget figure

Step 4

Prior to undertaking more detailed planning, it recommended that an initial M&V budget is determined and evaluated.

The IPMVP protocol suggests a M&V budget of up to 3-5% of annual project savings. The final budget will be affected by the chosen option, desired accuracy, type and length of measurement, and other factors such as resources.

Alternatively, FEMP M&V Guidelines[2] suggests the following allowances as a proportion of project implementation costs:

[2] M&V Guidelines for Energy Efficiency Projects v2.2 – Federal Energy Management Program, US Department of Energy

Table 5: M&V estimated costs for budgeting

M&V option	How savings are calculated	Cost (as percent of construction costs) (FEMP M&V Guidelines Section II Chapter 5 Table 5.1)
Option A	Engineering calculations using spot or short-term measurements, computer simulations, and/or historical data	1%—5%
Option B	Engineering calculations using metered data	3—10%
Option C	Analysis of utility meter data using techniques from simple billing comparison to multivariate regression analysis	1%—10%
Option D	Calibrated energy simulation/modelling calibrated with utility billing data and/or end-use metering	3%—10%

Source: Australian Best Practice Guide to Measurement & Verification of Energy Savings Table 7.2 p52

The budget will be finalised in Step 8, once the approach has been defined, and the resulting tasks and resources have been determined.

The M&V planning spreadsheet that accompanies this guide can be used to assist with preliminary cost estimation and final budget.

Outcomes from this step

1. Preliminary M&V budget figure

3.6 Select M&V Option, measurement boundary and key parameters

Step 5

With the necessary background information at hand, the next step is to review the available choices regarding M&V Option, measurement boundary and key parameters to determine the preferred approach.

When completing this step additional assistance is provided within:

- *Process Guide*: Section 4 for detailed definitions for key terms and Appendix A for design examples
- *Applications Guide* that is relevant to your particular ECM for decision making tips and considerations and scenario examples.

The choices for M&V Option, measurement boundary, and key parameters are co-dependent, and with this understanding, we are faced with the question, “which decision should be made first?” There may only be one option available, however in most situations two or more will exist.

Methods for making M&V design decisions

The table below describes three methods that can be applied to assist with decision making. Within each method, a primary parameter is evaluated first, in order to help finalise the remaining two.

Table 6: M&V decision making methods

Decision making method	Description	When is this method useful?
M&V Option: 1. Select Option 2. Define Boundary 3. Select Key Parameters	The preferred M&V Option is decided first, which then dictates either a project or facility measurement boundary. The boundary is then defined to capture the effects of the ECM, based on the independent variables Finally the required key parameters are identified and data collection and analysis is specified	An option-based approach may be considered when: 1. Timing is important – Options A/B may be employed where only short term measurement is available, or Option C where ongoing M&V is needed 2. Baseline data is not available – Option D 3. External requirements or incentives regarding verification or access to funding or white certificates 4. Cost is important
Measurement boundary 1. Select boundary 2. Select key parameters 3. Select Option	The measurement boundary is selected first, eliminating two M&V Options, with two remaining. Where a project boundary is chosen, the key parameters and independent variables are identified The effects ECM is considered in deciding whether key or full parameter measurement is required Where a facility boundary is chosen, the availability of baseline data is considered	A measurement boundary approach may be considered when: 1. The ECM or site complexity favours a project or site boundary 2. Desired focus on a particular ECM or aggregated site savings
Available data sources for parameters and independent variables 1. Select key parameters 2. Define boundary 3. Select Option	The key parameters are selected first, based on a review of the ECM, independent variables and available data. The measurement boundary is then defined, which may be clearly defined by the source of available data (e.g. sub meter). In some cases both facility and project boundaries are available. The M&V Option is chosen based on the nature of the ECM within the boundary.	A data focussed approach may be considered when: 1. The cost of data collection is to be minimised 2. Ongoing M&V is needed and will utilise existing data sources 3. The available data points clearly define a measurement boundary

A combination of M&V approaches may be used, and two approaches may be defined for the same ECM (for example Options A and C for a chiller upgrade).

No matter which decision making method is used, the fundamental requirement and guiding design principle for successful M&V remains the ability to design an approach consisting of M&V Option, measurement boundary and key parameters, that will enable baseline data to be adjusted according to changes in independent variables within the post-retrofit period to calculate actual or normal savings.

M&V Options

Depending on the method of evaluation, the M&V Option is chosen first or last. Each of the IPMVP Options has restrictions on its use, and it is important that the ineligible options are eliminated. In addition, the skills of the people involved may also be an influencing factor regarding option availability.

The following are some key questions to consider when selecting the M&V Option. If the M&V Option is being evaluated first, then these will assist with ranking the options. In contrast, if the M&V Option is being evaluated last, then these questions should be reviewed to ensure that the remaining choices fit with the desired outcomes.

- Do I wish to assess total energy use or assess a particular retrofit?
- For multiple ECMs, are there any additionality issues?
- What are the data requirements? Is data already available?
- Can a suitable energy model be developed?
- Am I seeking short-term vs. long-term measurement?
- Am I interested in once-off or ongoing M&V?
- Can a suitable project boundary be defined (for Options A and B)?
- What are the likely measurement costs? What metering is in place?

Use the considerations with corresponding traffic lights against each option in the matrix below to rule out any ineligible options, or nominate preferred options based on available skills.

Table 7: Suggested M&V Options based on design criteria

Suggested M&V Options	Option Available? 🟢 = YES 🔴 = NO 🟡 = POTENTIALLY AVAILABLE			
	A	B	C	D
Ability to determine savings of individual ECMs	🟢	🟢	🔴	🟢
Assess at facility or building level?	🔴	🔴	🟢	🟢
Savings less than 10% of total consumption?	🟢	🟢	🔴	🟢
Multiple ECMs?	🟡	🟡	🟢	🟢
Relationship of influence variables with energy use or demand is unclear	🔴	🟢	🟢	🟢
Interactive effects between ECMs are significant or not measurable	🔴	🔴	🟢	🟢
Expect many future changes to non-ECM factors within measurement boundary	🟢	🔴	🔴	🟢
Long-term savings determination	🟢	🔴	🟢	🔴
No base year data	🔴	🔴	🔴	🟢
Other considerations	A	B	C	D
Need non-technical persons to understand results	🟢	🟢	🟢	🟡
Have metering and instrumentation skills and experience	🟢	🟢	🟡	🟡
Have simulation skills and experience?	🟡	🟡	🟡	🟢
Have skills in reading utility bills?	🟡	🟡	🟢	🟡
Type of ECM Technology	🟢	🟢	🟢	🟢

Source: IPMVP 1:2012, Table 3, pg 34

The final decision will be based on weighing up the remaining options against the nature of the ECM and the intended outcomes.

Refer to Section 4.1.1 of the *Process Guide* for further guidance with understanding M&V Options and a decision tree for selecting the most appropriate M&V Option.

Measurement boundary

For options C and D, the measurement boundary should be clear – typically a whole building, or a major sub-section within a large, complex site. The energy use will be metered at the boundary using permanent equipment.

For options A and B, the measurement boundary may be small or large in its physical nature as well as energy use.

Boundaries will typically be defined in relation to:

(a) a piece of equipment (i.e. a pump or fan, compressor, lighting circuit)

(b) a physical space (i.e. room, floor, production line)

(c) an energy system (i.e. ventilation system, condenser water loop)

(d) or may be a combination of these

Selecting an Option A or B boundary involves a review of the ECM, its proposed effect (i.e. what will be affected and where), and the independent variables that also affect underlying energy use.

Once finalised, it is important to appropriately document the measurement boundary definition. This can be achieved using both words and diagrams. A good boundary definition should be easily understood by someone who is not intimately involved in the project.

Tips for documenting your measurement boundary

- be succinct, but not at the expense of clarity. Try to summarise the measurement boundary within a paragraph.
- draw or mark up diagrams to highlight the boundary. This can also be used for noting where measurement equipment will be placed,
- include references to the specific areas, equipment, and/or systems that sit within the boundary. Make sure to put this into context.
- if necessary, include the reasons why the nominated boundary was chosen, by relating to it to the nature of the ECM, and identified independent variables and key measurement parameters.
- note or illustrate any interactive effects that have been identified, which will affect energy use outside the boundary.

Refer to Section 4.1.2 of the *Process Guide* for further guidance with selecting a boundary and example boundary statements. Refer to Appendix A within the *Process Guide* for an example that explores various measurement boundaries for the same ECM.

Key parameters

In the context of the specific ECM, we need to determine the list of data parameters that must be considered in order to apply the M&V savings calculation.

Recalling the basic M&V savings equation, energy savings are calculated by subtracting post-retrofit energy usage from an adjusted baseline. In a basic case, the energy savings are determined by simply subtracting post-retrofit usage from baseline usage.

However in non-trivial cases, we need to consider the effect of Independent Variables found within the measurement boundary which cause regular changes in energy usage patterns, as well as non-routine changes. The collection and analysis of data for independent variables will enable us to adjust the baseline (i.e. determine ‘business as usual’) within the post-retrofit period, which then facilitates the calculation of actual savings.

Thus, we wish to identify all ‘key’ parameters that relate to:
- baseline and post-retrofit energy use
- routine adjustments
- non-routine adjustments

Once the relevant parameters are determined, we need to decide which parameters are to be:
- measured
- estimated or stipulated
- assumed constant or ignored

It is important to note that the list of parameters will vary depending on the choice of measurement boundary.

It is important to focus on the independent variables that affect energy use for the ECM, as well as the ECM’s performance outputs. For the latter, the measurement boundary needs to be defined to fully encompass the effect of the ECM, or otherwise be considered as interactive effects, depending on the effect.

The table below describes some sample ECMs, and lists suggested parameters to be considered for both ECM and facility boundaries. For Options A and B, only those parameters that directly affect the ECM need to be considered, whilst for Options C and D, additional site variables must also be included. Although we consider a wide range of parameters, some may not be required.

Table 8: Examples of key parameters to consider

Example site and ECM	**Parameters to consider**	
	Options A/B (ECM Boundary)	**Options C/D (Facility Boundary)**
School: lighting upgrade	▪ Lighting system power draw or energy use ▪ Lighting system operating hours ▪ Occupancy ▪ Available light levels ▪ School term and holiday schedule	▪ Site energy use ▪ Lighting system operating hours ▪ Overall site operating hours ▪ Ambient air temperature (where air conditioning is installed) ▪ Other site energy systems (e.g. dormitory, kitchen, gym, pool, playing fields)
Hospital: New Chiller control strategy	▪ Input energy ▪ Heating & cooling demand (hot/chilled water energy) ▪ Plant operating hours	▪ Site energy use ▪ Ambient air temperature (where air conditioning is installed) ▪ Site operating hours ▪ Occupancy

Example site and ECM	Parameters to consider	
	Options A/B (ECM Boundary)	Options C/D (Facility Boundary)
Commercial building: replace lifts	▪ Input energy ▪ Lift traffic – people movements	▪ Site energy use ▪ Ambient air temperature (where air conditioning is installed) ▪ Site operating hours ▪ Occupancy / vacancy
Plastics manufacturing: collect and reuse waste plastic	▪ Input energy use for the extruder or entire production line ▪ Input energy used in waste collection and treatment (e.g. shredder , pellet maker) ▪ Input raw material ▪ Units produced ▪ Operating hours (idle time vs. production hours) ▪ Seasonality ▪ Maintenance schedule	▪ Site energy use ▪ Input raw materials across all production lines ▪ Units produced across all production lines ▪ Site operating hours ▪ Site maintenance schedule ▪ Other site activities including warehouse (lighting), and administration (light/power/ air conditioning)

Suggested actions

1. Create a list of all parameters for measuring input energy use as well as independent variables that should be considered within the measurement boundary.
2. Use the measurement boundary to define the energy types and metering points for energy use
3. For each parameter, identify possible data sources, including proxies, and the frequency of data points
4. Decide which parameters to measure and which to estimate by considering each parameter's contribution to the overall uncertainty of the reported savings (i.e. measure the parameters with the largest uncertainty).
5. For the other parameters, review options to measure or estimate
6. Finalise the list based on decisions for M&V Option and measurement boundary.

Questions to consider

When attempting to identify parameters, ask yourself:

- What are the energy inputs at the measurement boundary? Where is the best place to measure energy use?
- What variables affect energy use for the ECM (e.g. occupancy hours, power draw, production, ambient temperature)? It is these variables that will form the basis for calculating adjustments.
- Which variables will be affected by the ECM? Which are unchanged? Where will the effects be seen? The measurement boundary needs to fully capture the effects of the ECM, and so should be defined to incorporate all affected areas/systems. Minor effects that sit outside the measurement boundary as known as interactive effects, and may be ignored if negligible.
- Can these parameters be measured? Can a proxy be used? Using a proxy consists of substituting a parameter we can't measure with an alternative that can be measured or for which data is already available.
- Are there any data collection issues? Refer to the table below.

Table 9: Data collection issues and suggested remedies

Data collection issues	Suggested remedies
Physical access constraints (i.e. underground, not enough space, metering equipment can't be fitted)	▪ Look for an alternative location to collect the data (e.g. underground pump – collect data at the distribution board, not the pump itself)
Parameter is difficult or impossible to measure	▪ Look for an alternative parameter that can serve as a proxy. ▪ Adjust the measurement boundary to either eliminate parameter, or enable a proxy to be used. ▪ Consider estimating.
Data sensitivity or confidentiality (i.e. consumer traffic, revenue related, troop/transport movements in defence sites)	▪ Consider ways to extract only the data that is required – (e.g. separating products sold from revenue earned) ▪ Consider ways to manipulate the data to mask the underlying figures without compromising integrity (perhaps represent as percentages using a reference point, rather than the actual figures) ▪ Look at having the analysis conducted by authorised people and report results only. ▪ Consider estimating using a standard set of conditions that can be correlated to energy use
Low data frequency or incompleteness (monthly production figures, annual weather totals)	▪ Look at ways to increase the frequency of collection. This may involve setting up methods to record readings manually (e.g. setting up trend logs on a Building Management System to obtain interval data) ▪ Investigate to see if the same data type with a higher frequency is available from another source (e.g. monthly production figures from Operations Manager's spreadsheet vs. data from production line SCADA system). ▪ Use gap filling techniques to fill minor data gaps.
Data lacks credibility or accuracy (data is available from an uncalibrated meter)	▪ Calibrate, replace or supplement the metering. ▪ Look for a different source for the same data (e.g. use Bureau weather data if a local sensor is not sufficient) ▪ Lengthen the measurement period to reduce uncertainty ▪ Consider estimating using the available data as a guide (i.e. the metered value becomes an estimate) ▪ Use as-is, making sure to incorporate the greater uncertainty in the savings calculation
Data is widely distributed and cannot be collected in one place	▪ Consider dividing the M&V exercise into multiple smaller projects ▪ Consider a sample-based approach for collecting data ▪ Consider adjusting the measurement boundary ▪ Review the chosen M&V option

Refer to Section 4.1.3 of the *Process Guide* for further guidance regarding key parameters.

Refer to the *Applications Guide* relevant to your type of ECM for suggestions regarding choice of key parameters, potential data sources and data collection tips.

Outcomes from this step

1. Nominated M&V Option
2. Defined measurement boundary and interactive effects

3. List of key parameters including:
   a. Ranked list of parameters to be measured, estimated or considered
   b. List of independent variables that will affect baseline energy use to be used to calculate adjustments

3.7 Determine measurement requirements and calculation methods

Step 6

With the boundary, key parameters and independent variables selected, the next step is to determine the requirements for conducting measurements, relating to:

- data sources for key parameters and independent variables
- required equipment (existing and new, temporary / permanent)
- desired interval for collecting data points (seconds, minutes, hours, days)
- placement of equipment
- measurement accuracy of equipment (precision)
- required measurement duration to cover one cycle

Options and considerations for equipment include:

- purchase, hire or borrow
- use existing meter or data (adjust measurement boundary if needed)
- availability of equipment

Measurement frequency

In addition to the length of measurement (i.e. measurement period) the frequency should be considered (i.e. interval between data collection points). For periodic measurements, the frequency should be decided based on the expected variation in the parameter. This could be anywhere from spot measurement, to periodic, to continuous.

Continuous measurement is best as it provides greater certainty in reported savings. Periodic measurement is possible for parameters that cannot be continuously metered, using techniques such as direct observation.

Sampling

Sampling is an effective approach for reducing the costs associated with capturing data in the following situations:

- periodic readings of the same thing (e.g. chilled water load, power draw)
- sampling a subset of total ECM (e.g. selected lighting circuits)

In the latter case, an important step is to establish that the chosen subset sufficiently reflects the population.

In both cases the use of sampling introduces uncertainty as we are using a snapshot rather than the complete picture. This uncertainty can be reduced by choosing suitable sample sizes and the homogeneous nature of the population.

Specifying the approach for developing the energy model and calculating savings

In Section 2.3 of the *Process Guide*, we introduced the basic savings equation, which is based on comparing actual performance against an adjusted baseline. Within this step we need to develop and document the methodology describing how savings will be calculated using techniques like an energy model.

With our key parameters known we can consider the tools and techniques to be used to manipulate the measured data to develop the baseline energy model.

Further guidance for analysis approaches is described in Section 5.2 of the *Process Guide*.

The M&V plan should contain description of the process and tools by which data will be analysed. Key steps should be included, such as aggregation, use of sampling and trend lines. The plan should address methods for both savings and uncertainty.

M&V accuracy

Driving factors:

- Measurement equipment accuracy
- Sampling frequency and sample size
- The amount of deviation between baseline data and the baseline model
- Validity of assumptions

Improvements can be made by using more accurate equipment, larger sample sizes, more frequent samples and choosing to measure rather than estimate.

Each trade-off should be considered against its cost.

Tips

- Where available, obtain a sample of data to review data fields, overall data variability, completeness and difficultly to obtain. Conduct a sanity check to review accuracy.
- Consider alternate methods for collecting the data where it appears as though the measurement costs will be too high. Alternatively, consider a sample based approach (selected readings, selected circuits)
- Measurement may be continuous or periodic
- Investigate using sampling to lower costs, or reduce measurement periods. The sample must be representative.
- Note that if a savings computation involves subtracting a measured parameter from an estimated parameter, the result is an estimate.
- If equipment is removed between readings, ensure that the M&V plan describes the specifications and calibration requirements of the measurement devices as well as its placement.
- Determine expected accuracy using estimated data and known quantitative uncertainties
- Parameters that are not expected to change can be measured immediately after the ECM is implemented and checked occasionally during the post-retrofit period.

Outcomes from this step

1. List of required equipment
2. Proposed techniques for collecting data (approach, placement)
3. Methodology for manipulating baseline and post-retrofit data to calculate savings
4. Methodology for estimating savings uncertainty

3.8 Develop your project task list and timeline

Step 7

With the information gathered thus far, a step-by-step task list can be developed. The result will be a detailed list of sequential tasks based on the M&V process, each describing an action.

The task list may be as simple or detailed as required, and tailored to suit various factors including the specific ECM, the chosen M&V option, site specific issues, desired outcomes, etc.

The tasks should be ordered in the sequence that they are likely to be conducted, to assist with scheduling. Once the task list is defined, resources and a budget time allocation are assigned to each task.

Organisations are encouraged to use existing internal processes and templates for developing and documenting project planning.

The list below provides a guide for the task areas that may be included:

Table 10: Suggested areas to be covered within M&V task list

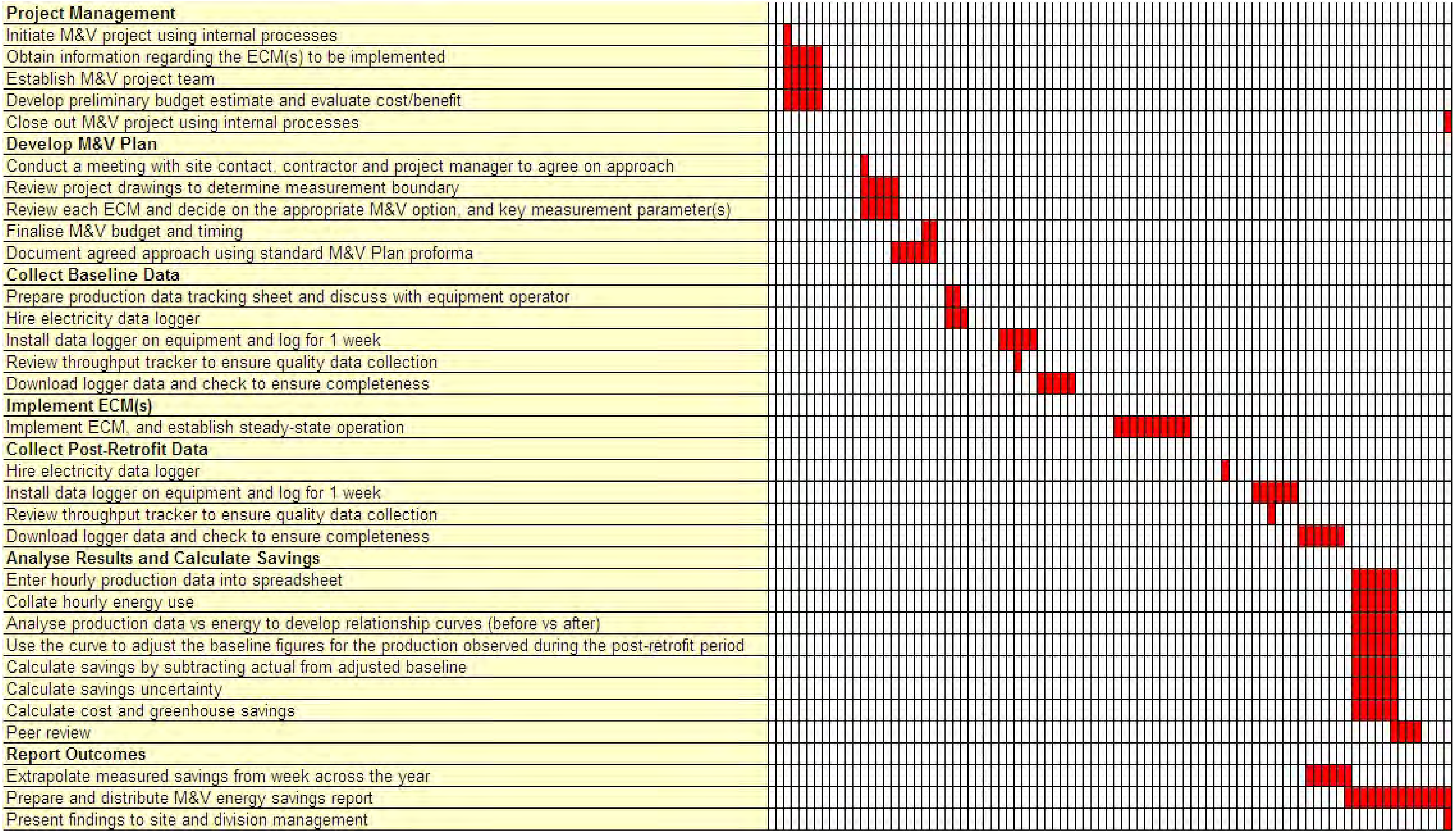
Key Area	Potential Tasks
Project management	▪ Initiating and closing out the M&V project using internal processes ▪ Project management progress reporting ▪ Meetings with project team and/or stakeholders
M&V planning	▪ Tasks within the 10 steps outlined within this section
Baseline data collection	▪ Purchasing or hiring equipment ▪ Placing and removing equipment ▪ Periodic checking to confirm data is be collected satisfactorily
ECM implementation	▪ Confirming key dates ▪ Obtaining relevant ECM information that may affect M&V outcome (configuration settings, as built drawings, etc)
Post-retrofit data collection	▪ Purchasing or hiring equipment ▪ Placing and removing equipment ▪ Periodic checking to confirm data is be collected satisfactorily

Key Area	Potential Tasks
Data analysis and savings calculations	▪ Acquiring required analysis and calculation tools ▪ Acquiring related data ▪ Downloading and manipulating data ▪ Developing calculation spreadsheets ▪ Calculating energy savings and uncertainty ▪ Calculating cost and greenhouse savings ▪ Peer review / quality assurance of calculations
Reporting outcomes	▪ Extrapolating savings from post-retrofit period ▪ Preparing and distributing M&V energy savings reports ▪ Preparing and presenting findings

With the tasks defined, the overall project timeline can be developed. This can be achieved in a number of ways using a variety of tools. A highly visual and effective method is to use a Gantt chart, which represents the tasks within a project across a timeline.

A sample Gantt Chart is shown below:

Figure 4: Sample M&V project timeline (Gantt Chart)



Whether a Gantt chart is used or not, the key tasks are to forecast commencement and completion dates for each task and allocate the resources and equipment required to complete.

The M&V project timeline must be linked to the overall ECM implementation timeline, and so it is important that the key implementation dates are added first.

Once these firm milestones are in place the remaining tasks can be scheduled so that the necessary planning, preparation and baseline data collection occurs before the ECM is implemented.

Within this step, the dates for the baseline and post-retrofit periods will be established. These should be reviewed in conjunction with the M&V Option and 'operating cycle' within the measurement boundary to confirm that adequate time periods have been allowed for.

Tips

1. Add the ECM implementation key dates to the timeline first and use these as the basis for M&V scheduling.
2. Be sure to allow enough time for baseline data collection and review, as this data may be unavailable once the ECM is implemented.
3. Taking into consideration the point above, aim to minimise changes to the site usage patterns through independent variables by nominating the baseline data collection period to be as near to the implementation date as is feasible, ensuring it covers at least one cycle of site operation.
4. Factor in the availability of resources and equipment, and travel time.

The M&V planning spreadsheet that accompanies this guide can be used to assist with preparing a detailed task list and project timeline.

Outcomes from this step

1. Detailed task listing with sizing (hours/days) and resource allocation (person, role)
2. Project schedule, listing the start and completion of each task and for the overall project

3.9 Finalise your M&V budget

Step 8

Whether your business is small or large, there are a number of features common to the development of a M&V project budget. Bearing in mind that the more complex the project, additional factors may need to be considered or different methods, however the guidance below provides the essential elements. It is important too that your budget is set up within your business' existing systems.

From the task list defined in the previous section, we can develop a detailed budget which will incorporate:

- labour costs
- equipment purchase/hiring costs
- use of consultants and/or subcontractors (e.g. electricians)
- other expenses including travel, meals, software purchases, fees for data provision from 3rd parties (e.g. Bureau of Meteorology), etc

Labour costs can be calculated by applying an hourly or daily cost rate to each resource within the project team, and multiplying this by the forecast time to be spent on the job. This is then summated for all resources within the project.

Quotes can be obtained for the purchase or hire of equipment as well as the use of consultants and subcontractors. In this area, it is important to note that there are two periods of data collection.

The table below illustrates a sample M&V budget. Labour costs are determined using total hours derived from individual task planning:

Figure 5: Sample M&V budget

BUDGET DETAILS				
Internal Expenses				
Resource (insert name/role)	Hourly Rate	# Hours	Total Cost	
Project Manager	$140.00	9.50	$1,330	
Site Manager	$120.00	2.00	$240	
Data analyst	$80.00	21.00	$1,680	
Electrician	$90.00	3.00	$270	
Other Internal Expenses			Total Cost	
Internal recharge for use of Shared Services Equipment			$300	
Total Internal Expenses				$3,820
External Expenses				
External Labour Costs (Consultants, Contractors)			Total Cost	
None			$0	
Other Expenditure (eg equipment)	Qty	Rate	Total Cost	
Hire Data loggers	2.00	$1,000	$2,000	
Total External Expenses				$2,000
Total Budget				$5,820

The M&V planning spreadsheet that accompanies this guide can be used to assist with finalising a M&V budget based on a detailed task list.

Outcomes from this step

1. Fully costed M&V project

3.10 Review M&V design

Step 9

Once all the design elements of the M&V plan have been decided, the overall design should be reviewed against the requirements and desired outcomes identified in Step 3 and the initial budget figure developed in Step 4.

Following this review it may be necessary to repeat Steps 5, 6, 7 and 8 for various M&V Options, in order to determine the preferred approach.

For example, you may consider alternative approaches that use ECM and Facility boundaries.

This review may be a quick sanity check, or a more formal review with the entire project team and decision makers.

Outcomes from this step

1. Confirmation that M&V design will satisfy all M&V objectives

3.11 Document your M&V Plan and obtain sign off

Step 10

Now that all the details have been worked out, the M&V plan can be prepared and signed off.

The final M&V plan can be prepared in various levels of detail, from a simple bullet point summary of the key elements to a comprehensive planning document.

In many cases a project is being planned or implemented within an energy efficiency program or as part of an energy performance contract. In these cases it is important to ensure that any additional required elements are included. Preferred or required M&V planning templates may be available to assist with presentation and layout.

Writing tips

1. Present the plan so that it can be easily understood by someone who is not directly involved in the project or who is a M&V novice
2. Write in plain language
3. Use SI units[3] for reporting all energy and other data
4. Provide background information on key terms or definitions, where it will assist with understanding
5. Ensure that units of measure are attached to quantitative figures, if not immediately clear.

The M&V planning spreadsheet that accompanies this guide is intended to form a complete M&V plan. Contents may be transferred into proposals or presentations if required to assist with business case approval.

Outcomes from this step

1. Complete M&V plan.

[3] International System of Units – also known as the metric system.

4 Additional Resources

4.1 Example M&V plans

The table below provides links to examples of M&V plans for a variety of projects that range in nature and complexity. Each is presented in its own style however they all share similar characteristics and key elements.

Table 11: Example M&V plans

Example	Reference
Standard M&V Plan for lighting retrofit Chiller replacement projects – standard M&V Plan	Berkley Lab: http://mnv.lbl.gov/qato
M&V Plan template	Federal Energy Management Program, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy http://www1.eere.energy.gov/femp/pdfs/6_3_reviewingmvplans.pdf
Appendix B – M&V Plan outline	Australian Best Practice Guide for Measurement and Verification (ABPG) – Australasian Energy Performance Contracting Association, 2004 www.eec.org.au/Best%20Practice%20Guides
Appendix A – 12 example cases which include M&V design (available for separate download)	International Performance Measurement and Verification Protocol (IPMVP) – Efficiency Valuation Organization (EVO 10000 - 1:2010) http://www.evo-world.org/index.php?option=com_content&view=category&layout=blog&id=655&Itemid=513&lang=es

4.2 Examples from this guide

The table below lists the example M&V projects that can be found within this guide.

Table 12: Example M&V projects from the M&V Operational Guide

M&V Project Name	IPMVP Option	Location
M&V design examples	A, B, C, D	Process: Appendix A
Demand and cost avoidance calculation example	n/a	Process: Appendix A
Regression modelling and validity testing	n/a	Process: Appendix E
Lighting fixture replacement within an office tenancy	A	Applications: Lighting – Scenario A
Lighting fixture and control upgrade at a function centre	A	Applications: Lighting – Scenario B

M&V Project Name	IPMVP Option	Location
Lighting fixture retrofit incorporating daylight control	B	Applications: Lighting – Scenario C
Pump retrofit and motor replacement	A	Applications: Motors, Pumps and Fans – Scenario A
Car park ventilation involving CO monitoring and variable speed drive on fans	B	Applications: Motors, Pumps and Fans – Scenario B
Replacement an inefficient gas boiler with a high efficiency one	C	Applications: Heating, Ventilation and Cooling – Scenario A
Upgrade freezer controls within a food processing plant	B	Applications: Commercial and Industrial Refrigeration – Scenario A
Compressed air leak detection within a manufacturing site using sampling analysis	B	Applications: Boilers, Steam and Compressed Air – Scenario A
Steam system leak detection within a food processing site using regression analysis	B	Applications: Boilers, Steam and Compressed Air – Scenario B
Multiple ECMs involving compressed air and steam system optimisation, combined with lighting controls at a cannery	C	Applications: Whole Buildings – Scenario A
Commercial building air conditioning central plant upgrade	C	Applications: Whole Buildings – Scenario B
Evaluate performance efficiency of a newly installed cogeneration unit a a school	D	Applications: Renewables and Cogeneration – Scenario A
Installation of a cogeneration plant at a hospital	C	Applications: Renewables and Cogeneration – Scenario B
Use of solar hot water system on a housing estate	B	Applications: Renewables and Cogeneration – Scenario C