Department of Climate Change, Energy, the Environment and Water

Guide to measurement and verification of energy efficiency projects in Australia

Module 1

August 2024

NSW GOVERNMENT

The measurement and verification (M&V) guide has 2 aims:

- Introduce M&V to the layperson who has an interest in the accurate and transparent determination of energy savings arising from energy efficiency measures (EEMs), and an interest in ensuring that the EEM continues to deliver savings, well after it was deployed.
- Provide a process and checklist for M&V practitioners to follow to deliver trustworthy M&V and to help ensure the persistence of savings.

As a result, this guide aims to contribute to better M&V practices and processes in Australia.

Acknowledgment of Country The Department of Climate Change, Energy, the Environment and Water acknowledges that it stands on Aboriginal land. We acknowledge the Traditional Custodians of the land and we show our respect for Elders past, present and emerging through thoughtful and collaborative approaches to our work, seeking to demonstrate our ongoing commitment to providing places in which Aboriginal people are included socially, culturally and economically.

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Section 1: M&V overview

This section is for audiences seeking a basic understanding of M&V and how to maximise its benefits.

1 M&V overview

1.1 About M&V

Energy savings represent the absence of energy use. Although it is not possible to directly measure something that does not exist, measurement and verification (M&V) is a way to 'measure' energy savings by determining what the energy use would have been in the absence of the energy efficiency measure (EEM) (modelled energy use), then subtracting actual energy use.

This is shown in Figure 1, a diagram developed by the Efficiency Valuation Organization (EVO®), the owners of the International Performance Measurement and Verification Protocol (IPMVP).

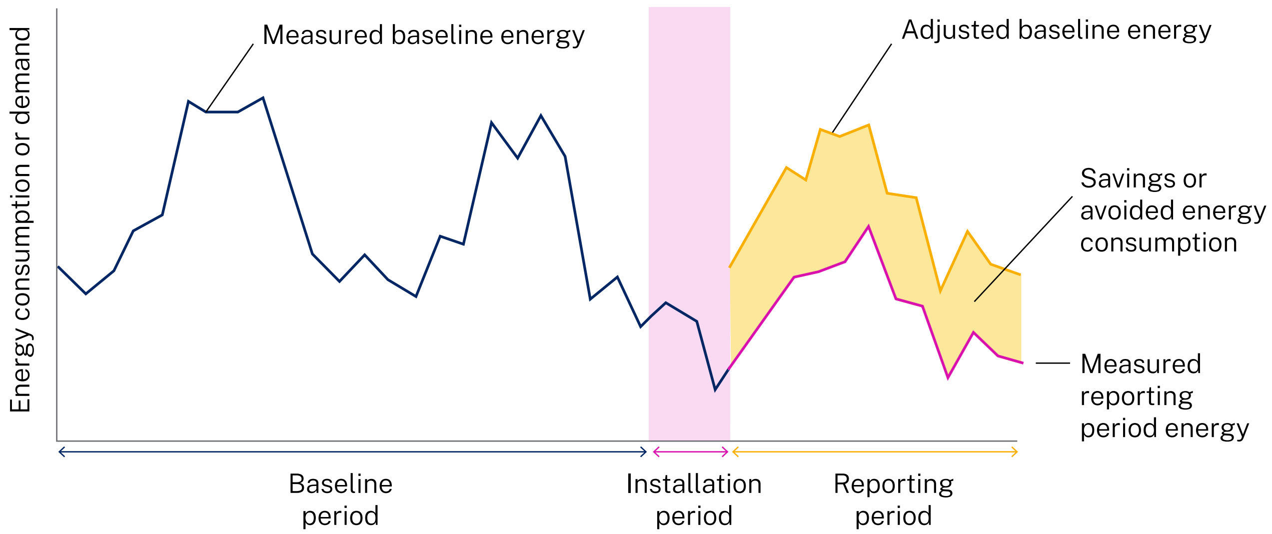


Figure 1 How to determine avoided energy usage (from IPMVP Core Concepts 2022)

It is important that the model of what energy use would have been in the absence of the EEM is appropriate for the conditions present during the reporting period (after implementation of the EEM). Only then can there be a like-for-like comparison of the before and after scenarios and a fair determination of the savings. For example, if the EEM had been implemented in a factory, the model would need to be adjusted to account for any changes in production.

The **measurement** of energy savings involves:

- measurements before and after the implementation of EEMs
- analysis (including developing mathematical models) to determine energy savings, based on the measurements undertaken.

Verification is the process of verifying that the EEM is operating as expected. It also involves ongoing routine monitoring to verify that the EEM continues to operate effectively and save energy.

A key principle of M&V is that savings are based on field measurements coupled with analysis, and that savings are not deemed (estimated). For example, estimating that after a lighting upgrade power demand will fall by 10 kW, and estimating that the lights operate for 2,500 hours a year, resulting in a saving 25,000 kWh a year, is not M&V. The savings have been deemed, and no measurements were undertaken. M&V of savings can only be undertaken based on field measurements and analysis of measured data.

1.2 Where M&V fits into energy efficiency projects

For all parties to have confidence in producing energy savings, M&V must be thought of as an integral part of any energy efficiency project's planning, scheduling, and budgeting. This means that M&V activities should start when the EEM is first considered.

Within an organisation that is an energy user, someone should be given ownership for M&V. Typically this would be the person who was championing the EEM, and might be the energy manager or the sustainability manager. The greenhouse gas savings from energy efficiency projects are important for sustainability, so the sustainability manager should be informed of all M&V activities.

If savings are a large percentage of total site energy usage (typically greater than 10% of total site energy usage), utility meters may be used for M&V. However, if savings are small, dedicated meters on the energy supply to the equipment subject to the M&V must be installed.

Data from a complete operating cycle of energy consumption are needed to create the mathematical models that M&V relies on. For example, if energy use varies seasonally, a complete operating cycle is one year, covering all 4 seasons. This is a key reason as to why M&V must be considered as early as possible – so that any meters required can be installed in time to collect a full operating cycle of data before implementation of the EEM.

A common mistake in the New South Wales Energy Savings Scheme (ESS) and Victorian Energy Upgrades (VEU) programs is to engage accredited certificate providers (ACPs) and accredited persons (APs) too late in the planning process, often just before the EEM is due for installation. This is poor M&V practice, especially when the savings are small, because then dedicated meters, not utility meters, should be used to undertake M&V. This may even make it impossible to determine whether savings have occurred.

Key takeout

Leaving M&V efforts to just before EEM installation is poor practice and can lead to:

- high uncertainty in savings estimates
- inability to determine if there have been any savings at all
- overly complex M&V that is less trustworthy.

M&V planning must begin when the idea for the EEM is first seriously considered.

1.3 Purpose of M&V

A well designed and implemented M&V process:

- enables the determination of energy savings
- verifies that EEMs operate as intended
- increases savings by measuring and verifying the ongoing persistence of savings (which allows refinement of the EEM) as well as allowing issues to be identified more quickly
- enables access to government incentives for energy efficiency (e.g. white certificates, the sale of which can be used to offset the costs of the EEM)
- enables access to financing for energy efficiency projects because savings can be quantified in a trustworthy way
- enables additional benefits, beyond the direct savings achieved by the EEM
- enables the determination of return on investment.

M&V enables the determination of energy savings

M&V can be considered as the energy efficiency 'accountant', determining the ongoing energy and cost savings and calculating the return on investment. This also allows the determination of greenhouse gas emissions reductions. This will become increasingly important as we transition to net zero emissions.

M&V is particularly useful in verifying savings for energy performance contracts, white certificate schemes, and emissions reduction schemes.

EVO states:[1]

> While some stakeholders in the market claim that M&V is impractical due to time and expense, EVO does not believe these claims have merit for EE [energy efficiency] project investments.

1 EVO position statement on deemed savings, 22 October 2019

Investment in a power generation project without the installation of a meter to measure the energy generated would be unthinkable. Similarly, it is illogical to expect EE projects to be funded on a scalable basis without an M&V 'meter' to measure the energy saved and the associated return on investment.

It is also unreasonable to expect EE, as the cleanest and usually most cost-effective energy resource available, to be recognised as a sustainable and marketable commodity if its benefits are not properly measured on a consistent basis.

M&V verifies that EEMs operate as intended

Over the lifetime of an EEM, many factors (planned or unplanned) can cause underperformance, preventing the expected energy savings being realised. Following strong and ongoing M&V practices greatly reduces these risks. The process of verification involves confirming that EEMs are properly commissioned and operating as intended. Ongoing monitoring and the preparation of regular (usually annual) M&V savings reports helps ensure the persistence of savings.

If an EEM fails to perform as intended, the energy user may suffer financial losses that could have been avoided had the poor performance been identified and corrected immediately.

For example, Figure 2 shows the power produced by a rooftop solar PV system. For 4 months production was less than expected, and in one of these months it was zero! This resulted in lost savings of around 60 to 80 MWh.

Most of this loss could have been avoided had the performance of the system been closely monitored as part of ongoing M&V. This would have allowed immediate effective corrective action to be undertaken.

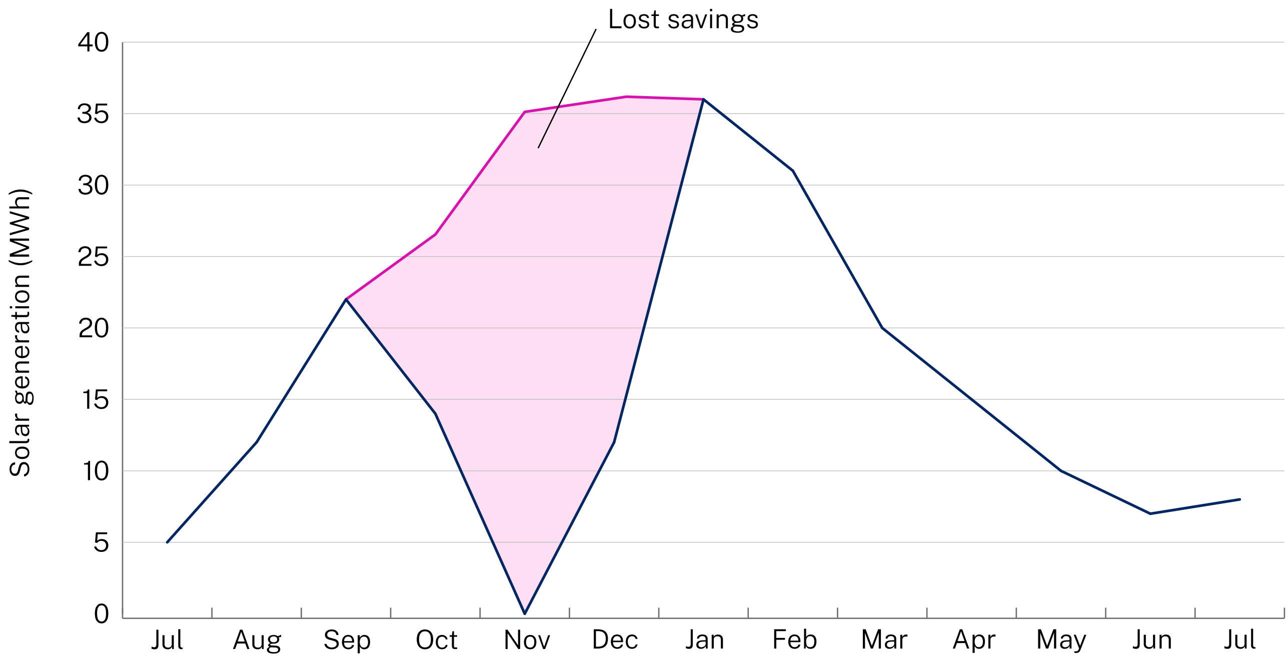


Figure 2 Example of energy losses due to poor monitoring

Some EEMs benefit greatly from ongoing M&V. This is true for EEMs for which the savings arise from control upgrades rather than equipment upgrades:

- Savings may be realised through improved control of the equipment, perhaps by a building management system (BMS) or supervisory control and data acquisition (SCADA) system, or by any sensor or time clock-based control system. The equipment may perform efficiently, but any savings are lost if the equipment is inefficiently controlled, or controls are bypassed. For example, a new maintenance contractor, unfamiliar with the EEM, could bypass or switch off the energy saving settings in a BMS.
- Savings may be achieved through the use of sensors that can turn off equipment when it is not needed. Sensors may fail, or be bypassed or removed – for example, occupancy sensors used to control lighting may be incorrectly configured, causing occupant annoyance, and may then be removed or disabled.
- Savings may arise from the deployment of variable-speed drives. Such drives can easily be reprogrammed – for example by a new maintenance contractor – to run the load, such as a pump or fan, at full speed.

EEMs that can easily be turned off also benefit from ongoing M&V, and include:

- solar PV systems, in which the inverter may be turned off (e.g. for maintenance) and not switched on again
- voltage optimisation equipment (in which the voltage optimisation unit can be bypassed).

EEMs that do not have a proven reputation for reliability benefit from ongoing M&V, and include:

- solar hot water systems (pump controllers or pumps may fail)
- power factor correction equipment (capacitors eventually fail)
- novel EEMs that do not yet have a reliable track record of savings.

Ongoing M&V activities help maintain savings.

When is ongoing monitoring not really needed?

When the EEM has a proven reputation for reliability, its performance is unrelated to control settings, and it cannot be disconnected.

M&V increases savings

'... retrofits that follow strong M&V practices ... experience energy savings that are on average about 20 to 30% higher ...'

By ensuring that there is a focus on measuring and verifying the persistence of savings, greater savings can be delivered.

> ... projects with strong M&V result in a substantially higher level of savings than projects that have little or no M&V.
>
> ... retrofits that follow strong M&V practices ... experience energy savings that are on average about 20 to 30% higher ...
>
> The added cost of a strong M&V program is typically about 5% of the retrofit cost, but is typically paid back in months ...[2]

M&V may enable access to government incentives for energy efficiency

State and territory governments and the Australian Government run white certificate schemes to incentivise the uptake of energy efficiency projects. M&V may enable:

- creating Energy Savings Certificates (ESCs) under the ESS
- creating Victorian Energy Efficiency Certificates (VEECs) in the VEU program
- the creation of Australian carbon credit units (ACCUs) using the industrial and commercial emissions reduction (ICER) method (ICER) method (ICER) method in the Australian Governmen's Emissions Reduction Fund (ERF).

The ESS and VEU are white certificate energy efficiency schemes, such that:

- the ESS uses M&V through the Project Impact Assessment with M&V (PIAM&V) method to create ESCs
- the VEU program uses M&V through the Project Based Activities M&V (PBA M&V) method to create VEECs.

Once created, white certificates may be sold and the proceeds of the sale used to cover the cost of M&V activities and offset the cost of the EEM.

ACCUs can be sold to the Australian Government to similarly offset project costs.

2 A best practice guide to measurement and verification of energy savings, Australasian Energy Performance Contracting Association, ISBN 0-646-44370-4, 2004, page 6

M&V enables access to financing for energy efficiency projects

M&V makes energy efficiency bankable by using robust, transparent methodologies to determine savings. It is used globally in energy performance contracts (EPCs) as the 'accountant' for determining the monetary value of energy savings.

Project sponsors may rely on M&V to determine the value of energy savings. One such institution is the Sustainable Australia Fund, in which repayments are attached to the property and are made through council rates. This fund requires evidence of savings to be provided, and this is done with M&V.

However, funding is limited to those local councils that are participating in the fund. Currently, most Victorian and several New South Wales and South Australian councils are participants; and the number of participants is increasing.

In Victoria, the Greener Government Buildings program uses M&V to determine the savings achieved from EPCs undertaken on government buildings, and has facilitated over $200m in financing.

Energy services companies (ESCOs) may also be able to provide EPC financing, either directly or from financial partners they are associated with.

Businesses can also use M&V to establish savings from projects implemented with funding from their own balance sheet and to validate the value of the investment.

EVO has developed the International Energy Efficiency Financing Protocol, which is intended to educate financing institutions such as banks about energy efficiency projects and how to use M&V to structure energy efficiency financing in a way that is low risk and commercially attractive.

Table 1 compares incentive and financing options enabled by M&V.

Table 1 Comparison of incentive financing options facilitated by M&V

Incentive or Financing Option	Plus	Minus	Comments
White certificate financing through the PIAM&V or PBA M&V methods	Well-established with clear methodologies These schemes allow the energy user to claim the greenhouse gas savings from the EEM	Incentives are only available retrospectively	NA

continues

Table 2 *continued*

Incentive or Financing Option	Plus	Minus	Comments
Federal Emissions Reduction Fund	Available across all of Australia	Best suited to larger projects only Incentives are only available retrospectively Funding is enabled by selling the ACCUs to the Australian Government. This means that the greenhouse gas savings become the property of the government and cannot be claimed as greenhouse gas savings achieved at the site where the EEM was implemented	Projects can be aggregated
Sustainable Australia Fund	Wide range of projects supported, can be used in addition to either the state white certificate schemes or the ERF	Limited to those local councils that support the Sustainable Australia Fund	NA
Greener Government Buildings financing	Established and proven with clear methodologies	Restricted to Victorian Government departments and agencies only	NA
ESCO financing	Wide range of projects supported, can be used in addition to either the state white certificate schemes or the ERF	Unless requested, savings determined by M&V are not verified or audited by a third party	A shared savings contract can incentivise larger savings

Enables benefits beyond the direct savings arising from the EEM

M&V can be viewed as a process of engagement, communication, measurement, monitoring and analysis that helps ensure that EEMs continue to save energy over their operational lifetime.

This process has benefits that go beyond the direct benefits of the EEMs. By focusing on an EEM and paying attention to its correct operation and ongoing savings, M&V opens the door to:

- enhancing the operation of an EEM to deliver savings that go beyond expectations (e.g. the losses shown in Figure 2 would not have been so high with effective M&V)

- increased awareness of other savings opportunities (e.g. installation of sub-meters as part of M&V can yield operational insights that open up further savings opportunities)
- a process of continual improvement (e.g. 'monitoring and targeting' is based on continuous M&V, and when accompanied by active energy management activities commonly delivers additional savings of around 3% a year).

1.4 Roles and responsibilities of M&V

Ensuring that M&V delivers its potential benefits requires effective communication, appropriate scoping, the preparation of reports, and long-term engagement with multiple stakeholders. Therefore, responsibility for M&V is shared by all stakeholders.

Each of the various activities involved in M&V is described in detail in chapter 3, as is who is responsible.

1.5 Process to undertake M&V

M&V is undertaken as follows:

1. **Initial planning** of M&V activities (such as what metering may need to be installed) begins when an EEM is first considered for implementation. Failure to plan may make it hard or impossible to develop a trustworthy baseline.
2. **Measurements** are made before the EEM is implemented to be able to create a baseline model that can be used to predict energy use after implementation of the EEM; preparing an **M&V plan** (incorporating the modelling described here) that spells out exactly how savings will be determined.
3. After implementation, **verification** ensures the EEM is working as intended.
4. **Measurements** are made after implementation of the EEM and used along with the mathematical models developed to determine savings.
5. **Savings reports** that are developed in line with the M&V plan and based on measurements undertaken over the reporting period, and that document the savings, are provided.
6. Ongoing **monitoring** (and M&V as needed) is used to ensure that savings persist.

These activities are supported by 2 key documents:

- **The M&V plan.** The M&V plan is a document that lays out how M&V will be undertaken, reports on the baseline energy use and presents the baseline model. It is prepared before the EEM is implemented.
- **M&V savings report.** The M&V savings report is a document that reports on the savings, as set out in the M&V plan. It is prepared after the EEM is implemented and is based on measurements undertaken in the reporting period.

Good M&V practice is to prepare regular (e.g. annual) M&V savings reports, based on ongoing measurements and analysis.

Energy users are advised to engage an M&V practitioner early on – well before the EEM is implemented – to undertake M&V. At this point M&V practitioners must know, among other things, what factors cause variations in energy consumption within the measurement boundary, how reliable the EEM is likely to be, and what the expected savings are as a percentage of site energy usage.

The decision about which M&V approach to use is important because it governs the need for installation of sub-metering, which must be used for long enough to establish a baseline. When choosing the M&V option, the expense of installing sub-metering should be balanced against its benefits – more accurate determination of savings and improved ability to detect failures in the performance of the EEM.

Key takeout

All parties – energy users, project sponsors, energy service providers and M&V practitioners – must make M&V integral to any energy efficiency project and allow sufficient budget and time for this – **before** implementing the EEM.

The baseline measurement period must encompass the full operating cycle from minimum energy consumption and demand through to maximum. It should also encompass the full ranges of all the variables that are known to impact on energy usage.

For example, in an ice-cream factory, the volume of ice-cream produced is an independent variable and varies seasonally (more in summer, less in winter). Therefore, 12 months of production data is needed to capture a representative baseline. This means that, in this example, M&V must start more than a year before EEMs are implemented. This is fairly typical.

M&V must continue after the EEM has been implemented for as long as there is a need to determine savings.

Verification checks that the EEM is operating as intended and that it continues to operate as intended. Monitoring detects site changes that may impact on the usefulness of the energy model(s) used to determine energy savings.

Quiz

Does the energy user need to keep the M&V practitioner informed of any site changes that may impact on how savings are determined?

Answer: Yes!

If there have been changes that may impact on how savings are determined, these must be accounted for when developing savings calculations and reports. For this reason, the energy user must keep track of site changes that may impact on energy usage and inform the M&V practitioner when such changes occur.

For example, a school might replace its old gas heaters with more efficient heaters. If at some later time the school expands and puts in more heaters, site energy use is affected, and so is determination of savings.

1.6 Determine your savings with M&V

Savings can be determined using either of 2 main ways: normalised savings or avoided energy use.

Avoided energy use

The answer to the key question 'what would energy use have been if the EEM had not been implemented' is commonly answered using linear regression modelling. A linear regression model establishes the relationship between energy consumption (as the dependent variable) and one or more independent variables. The independent variables are measurements of some parameters that, for logical reasons usually based on engineering or science, are expected to affect energy use.

For example, it is logical that outside air temperature would influence the electricity consumption of an air-conditioning system in summer. A linear regression model can be built to mathematically describe the correlation between electricity consumption and outside air temperature.

In the baseline period, before implementation of the EEM, a baseline regression model is built. After implementation of the EEM, by using the values of the independent variables during the reporting period it is possible to estimate what the baseline energy consumption would have been (that is, without the EEM) by using the baseline regression model (Figure 3).

For example, the baseline model may determine that, in a factory before the EEM is applied, gas usage depends on the number of widgets made in a month, N, and the equation is:

$$\text{Energy from gas (GJ)} = 1{,}000 + 100 \times N$$

In the reporting period, in a month in which 10 widgets were made, the equivalent baseline gas consumption (known as the adjusted baseline) would then be:

$$1{,}000 + 100 \times 10 = 2{,}000 \text{ GJ}$$

The difference between this estimate of what the baseline energy consumption would have been, and the actual energy consumption in the reporting period, is the **avoided energy use** due to the EEM.

Continuing the example above, if actual consumption in the reporting period (after the EEM is implemented) was 1,500 GJ, the avoided energy consumption in that month would be 2,000 – 1,500 = 500 GJ.

This technique of applying the conditions of the reporting period to the baseline model enables a like-for-like comparison, and thus a fair determination of savings.

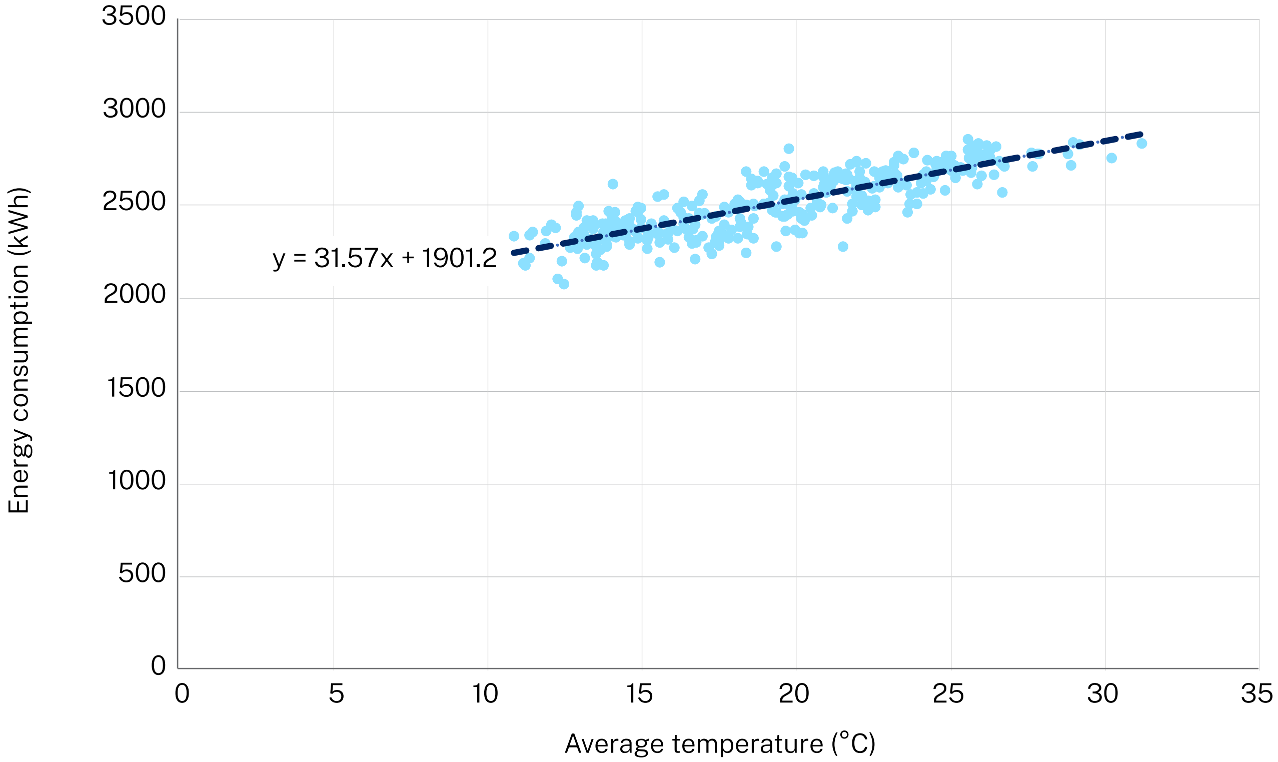


Figure 3 Example of a linear regression with energy use as the dependent variable (y) and average temperature as the independent variable (x)

Normalised savings

In this approach, in addition to developing a baseline model, a reporting period linear regression model is also developed.

Both models are then applied to a common set of independent variables that represent a typical year of operation for the equipment (a ‘normal year’). This is done to enable a like-for-like comparison of the scenarios before and after the EEM, and gives a better representation of what savings will be under ‘normal’ operating conditions than the avoided energy use method. The difference in consumption predicted by both models yields the normalised savings.

The normal year is representative of the expected normal values of the independent variables over the lifetime of the EEM. A normal year should include the expected normal means, ranges, and variations for all independent variables.

1.7 Costs associated with M&V

The M&V budget must include key costs:

- ☐ Developing a M&V plan and energy consumption baseline
- ☐ Verifying correct operation of EEMs
- ☐ Reporting on savings
- ☐ Monitoring and verification of ongoing correct operation of the EEM

Many activities have associated costs:

- ☐ Data collection
- ☐ Site visits
- ☐ Data analysis
- ☐ Meetings and communication
- ☐ Report preparation
- ☐ Quality control
- ☐ Maintenance of data collection systems
- ☐ Management and instigation of corrective actions

These costs vary from project to project. A common rule of thumb from the IPMVP is that M&V savings reporting costs[3] are around 3 to 5% of the annual savings and should be less than 10% of savings. Table 2 shows indicative M&V costs.

Table 2 Indicative M&V cost estimates. Costs may vary considerably from project to project, and metering costs can vary widely, depending on what is metered.

M&V activity	Using whole-of-site utility energy meters	Using sub-meters to only measure energy use of the equipment impacted by the EEM (including metering costs)[a]
M&V planning	$5,000	$11,000
Operational verification	$2,000	$2,000
M&V savings reporting[b]	$5,000	$7,000
Total	$12,000	$20,000

a Metering costs may vary widely.
b Reporting costs will depend on how long M&V activities continue.

3 This is the M&V savings reporting costs and does not include the cost of M&V planning.

2 Recommendations to maximise the value of M&V

M&V is a process of engagement, communication, measurement, monitoring and analysis that can help EEMs save energy and continue to save energy over their operational lifetime. This process has benefits that go beyond the direct benefits of the EEMs. By focusing on an EEM and paying attention to its correct operation and ongoing savings, M&V opens the door to:

- improved operation of an EEM so that it delivers savings that go beyond expectations
- increased awareness of other savings opportunities
- continuous improvement.

Following the process outlined in this document will help ensure that M&V does give these benefits. Typically, several factors cause M&V processes to underperform:

1. **Planning and communication skills:** 'Selling' the benefits of M&V to energy users and project sponsors when the EEM is first proposed is vital. For projects in which the savings are small – less than 10% of total site energy – installation of dedicated metering and collection of sufficient baseline data is crucial if savings are to be determined with enough accuracy and certainty. Only good planning and communication can ensure energy users understand this and invest in the needed metering.
2. **Statistical analysis:** Poor or wrong application of statistical techniques, including regression modelling and determination of uncertainty, prevents M&V from begin effective.
3. **Verification of correction operation of the EEM(s), monitoring, and ongoing reporting on savings:** Too often, this is not done at all. The consequence is that savings may not persist over time.

The following sections highlight specific best practice recommendations for the different M&V stakeholders. Following these will avoid many possible deficiencies in M&V processes.

2.1 Recommendations for energy users

- Allocate sufficient time and resources to M&V planning, including allowing sufficient time for metering and data collection before implementation of the EEM.
- Consider ensuring any M&V contract you enter gives you the right to share M&V data and reports with third parties, for the purposes of quality control (or even bragging about the savings achieved!).
- If anything is confusing and does not make sense, engage an independent M&V practitioner who has technical knowledge of the EEMs being implemented. This is good quality assurance practice.

- Insist that evidence of savings be provided and see that it agrees with common sense. For example, if you have been told site-wide energy savings are 20%, and there have been no changes at your site and in how the site is used, the overall energy consumption, as shown on your bills, should have dropped by around 15 to 25%. If it has not, the reasons must be clearly explained in the M&V savings report.
- Allocate time and resources to M&V for verification and monitoring activities – expect to have to act.
- Keep records of any activity happening in the facility that could affect the project and notify M&V practitioners of any changes on site over the duration of the M&V. This can give the M&V practitioner insights into what could be affecting the savings.
- Play a 'long game' if you wish to maximise the benefits of your investments to reduce energy usage, by using ongoing monitoring and verification over the lifetime of the EEM. Be prepared to invest a little to avoid losing a lot – this can happen when EEMs fail to continue to deliver savings but this is not detected. Failure is usually silent!
- Insist on evidence of persistence of savings through the regular preparation of M&V savings reports.
- Assign the responsibility for managing M&V to a role in your company, rather than an individual, to ensure continuity in case of personnel changes.

2.1.1 Energy managers and sustainability managers

Follow the advice for energy users, plus:

- develop an understanding of key M&V concepts.
- react quickly to data alerts – any data outages may make it difficult or impossible to determine savings.

2.2 Recommendations for project sponsors and management

- Develop an understanding of key M&V concepts.
- Insist that evidence of savings be provided and see that it agrees with common sense. For example, if you have been told site-wide energy savings are 20%, **and there have been no changes at your site and in how the site is used**, the overall energy consumption, as shown on your bills, should have dropped by around 15 to 25%. If it has not, the reasons must be clearly explained in the M&V savings report.
- Ensure that sufficient time and resources are allocated to M&V activities, from planning through to verification and reporting.
- Ensure that M&V is an integral part of the energy management role (in case of personnel change).

2.3 Recommendations for energy service providers

- View M&V as vital to delivering maximum value to your energy user client.
- Initiate M&V activities as soon as an EEM is being seriously considered.
- Freely share information with the M&V practitioner about the project – good M&V is of benefit to you both.
- Let the M&V practitioner lead the M&V process.

2.4 Recommendations for M&V practitioners

- When undertaking M&V, go through all the steps outlined in Figure 4 (see chapter 3) and follow the detailed checklists in that chapter.
- Take responsibility: You are the key person who will ensure whether M&V is done well or not.
- Take time to help the other parties (energy users, project sponsors, energy service providers) understand the benefits of M&V, the activities involved, and the expectations for their contributions.
- Streamline your systems so you can efficiently provide M&V services (e.g. make effective use of templates) and improve the value you offer.
- Choose independent variables carefully, in line with the guidance in this document. Inadequate data collection may prevent determination of savings.
- Ensure that there is enough data on static factors, and identify how any non-routine events will be accounted for.
- Undertake data analysis as outlined in this document.
- Test all energy models to make sure they are acceptable.
- Budget appropriately for verification and ongoing monitoring activities.

2.4.1 Recommendations for ACPs/APs

- Approach M&V with the attitude that the better the M&V, the lower the risk that savings from the EEM(s) cannot be clearly and accurately quantified.
- Meet regularly with your energy service providers so you can initiate M&V activities as early as possible.
- Budget for thorough M&V.

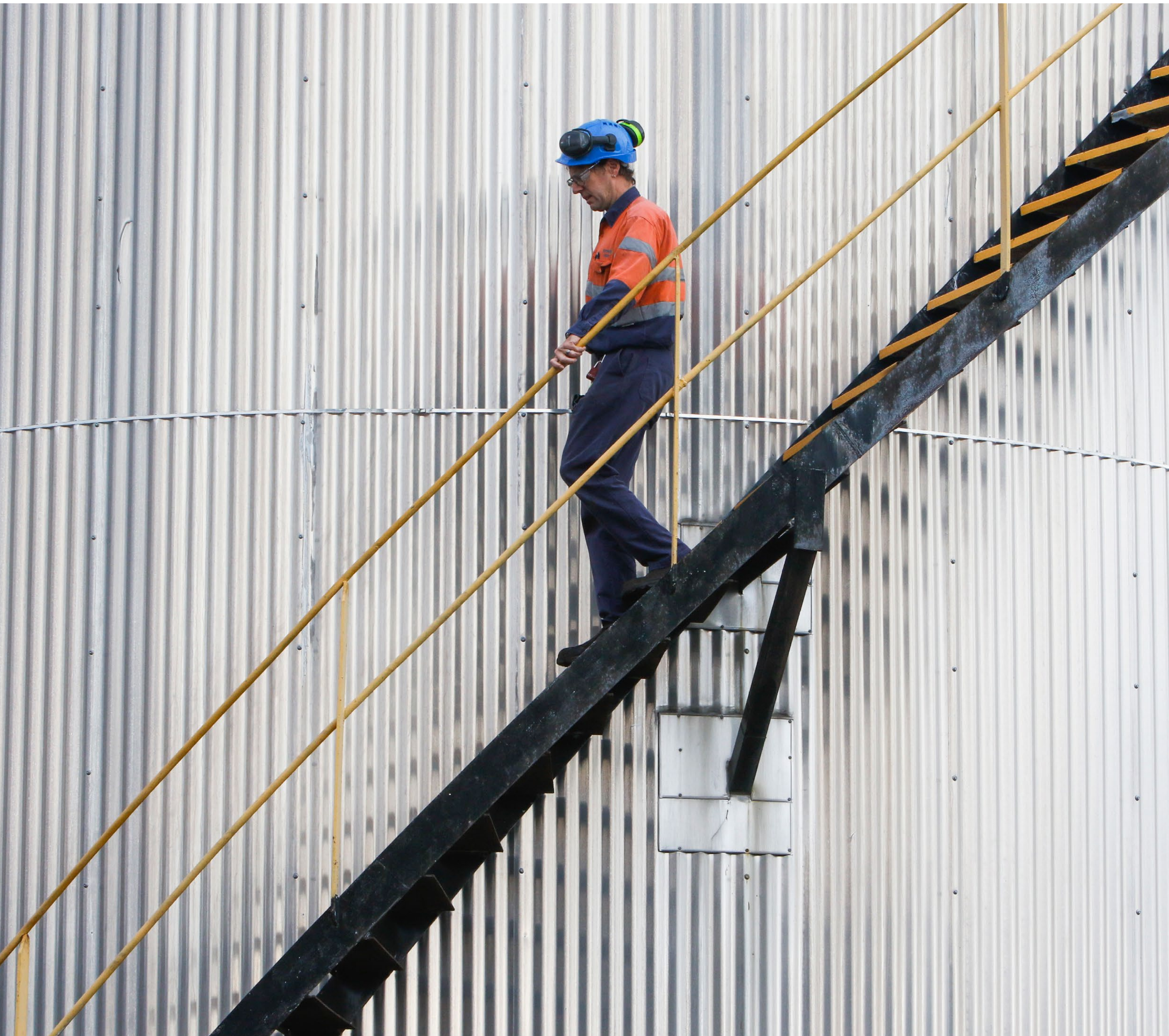
Section 2: M&V process

This section is for audiences seeking guidance on adopting a step-by-step approach to maximise the value of M&V.

3 M&V activities step-by-step

Effective M&V follows the steps outlined in the checklist (Figure 4). This chapter details the activities needed to complete each step. The checklist boxes are to be ticked off when the activities are completed.

Checklists are an effective way of ensuring that activities are undertaken thoroughly and are a proven way of ensuring consistency of outcomes. M&V can be a complex process. Using the checklists in this document can help to effectively manage this complexity. To facilitate effective meetings, use checklists 3.1, 3.4, 3.9 and 3.16 as meeting agendas.



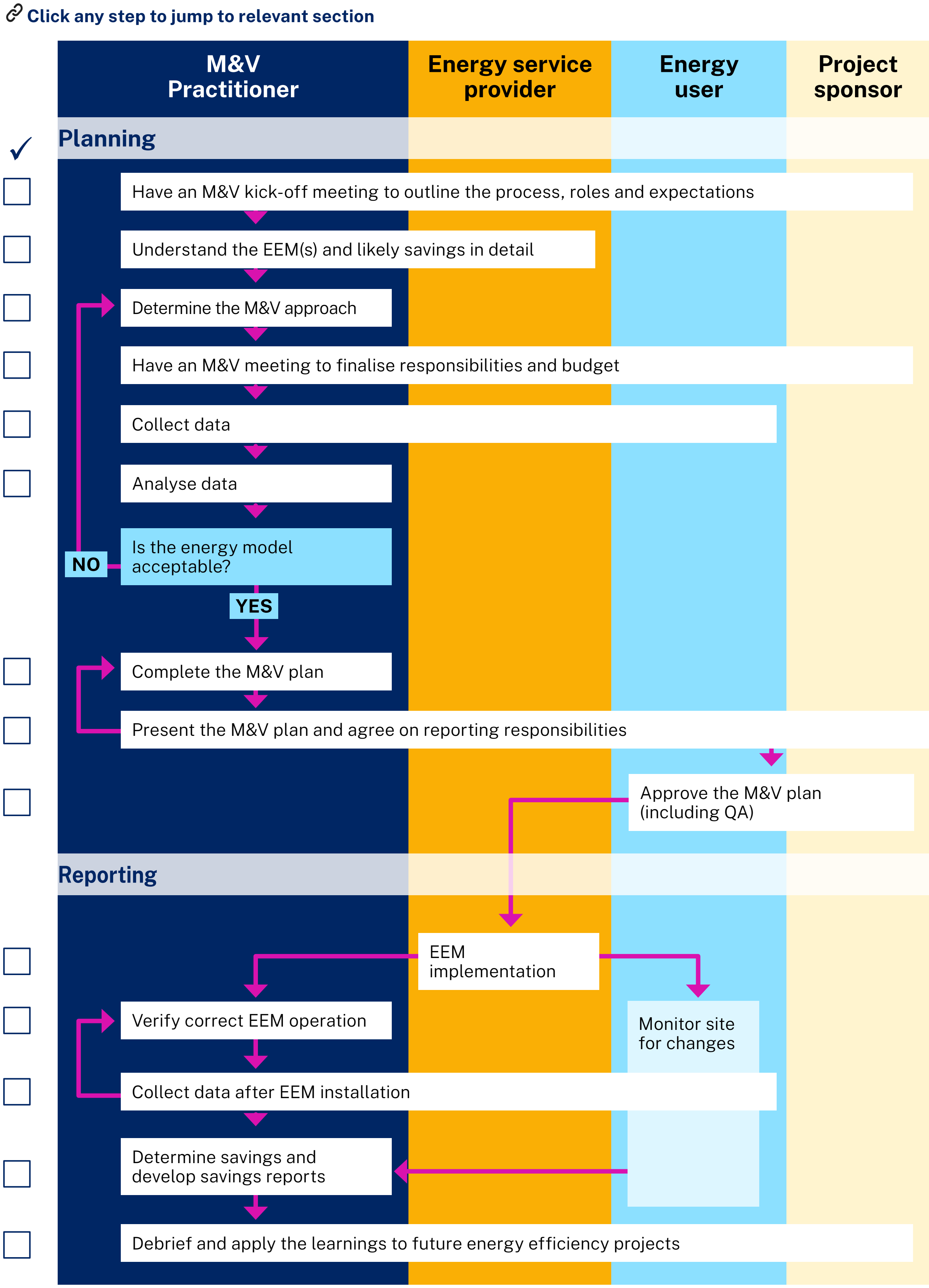


Figure 4 Step-by-step approach to maximise the value of M&V

3.1 Have an M&V kick-off meeting to outline the process, roles, expectations

✓	M&V Practitioner	Energy service provider	Energy user	Project sponsor
☐	Have an M&V kick-off meeting to outline the process, roles and expectations			

This meeting aims to align all stakeholders involved in the M&V process.

Because the energy user and the project sponsor may not have prior experience with the M&V process, the value and financial benefit of M&V must be clearly outlined and explained in the kick-off meeting.

Check that the kick-off meeting achieves all its goals:

- ☐ All parties understand the EEM in broad terms
- ☐ The energy user and project sponsor understand what M&V is, the value it provides, and how it is undertaken (examples of previous successful M&V plans and reports can be useful here)
- ☐ All parties have a clear understanding of their roles and responsibilities – what is expected of them, and when
- ☐ All parties agree on timelines, including allowing sufficient time to install metering, collect baseline data covering a complete operating cycle, and develop a robust energy model; this includes discussion about when the EEM will be installed
- ☐ All parties agree on M&V practitioner access to the site
- ☐ Preliminary agreement is reached on the accuracy level required for savings determination
- ☐ All parties discuss the importance of persistence of savings and for how long M&V activities must be undertaken to help ensure persistence of savings
- ☐ All parties take part in preliminary discussion on M&V budget
- ☐ Available and missing data are identified
- ☐ Parties gain understanding about likely changes at the site that will impact on energy consumption, and understand normal and abnormal operation
- ☐ Meeting minutes that cover all these points are prepared and circulated
- ☐ If the intent is to create ESCs or VEECs, the ESS or VEU scheme requirements are discussed.

Note to all parties

As poor early decisions about projects could limit the ability to undertake M&V, hold the kick-off meeting as early in the process as possible.

3.2 Understand the EEM(s) and likely savings in detail

✓ **M&V Practitioner** | **Energy service provider** | **Energy user** | **Project sponsor**

☐ Understand the EEM(s) and likely savings in detail

The M&V practitioner must understand the specifics of the site, and of the EEM. This understanding can be gained by consulting with the energy service provider.

Check that the following has been undertaken:

☐ Engagement with the energy service provider has taken place

☐ The site has been visited

☐ Equipment to be upgraded has been inspected (including the taking of, and clear labelling of, photos of the equipment subject to the proposed EEM)

☐ Non-utility meters, and meters for potential independent variables have been inspected and meter numbers and calibration details recorded

☐ It is understood what data are available, where they are sourced, how they are stored, and who is responsible for data collection

☐ A general appreciation for how site operations might impact on energy use is achieved

☐ Any plans for the site are understood, as is their impact on M&V and the number of years over which savings can be expected

The following should be understood and documented:

☐ Annual site energy usage, and variation in site energy usage in recent years

☐ The impacted equipment

☐ How the EEM saves energy

☐ The likely savings in energy units and as a percentage of total site energy usage

☐ The data and data sources used by the energy service provider to estimate savings

☐ The factors (i.e. potential independent variables) that are likely to cause variation in how much energy is used by the equipment subject to the EEM, and whether data is available on these factors – for example, one factor that may cause variation in the amount of energy used in a factory is the number of products manufactured; is data on production available?

☐ Any future site plans that will reduce the number of years over which savings can be expected (e.g. planned site closure in 5 years due to moving offshore)

If IPMVP option B will enable better M&V (e.g. because the expected savings are only a small percentage of energy use), the following should also be understood and documented:

☐ What sub-meters already exist that may be supplying the loads that will be subject to the EEM; in this case, documentation may include single-line diagrams

☐ How data are collected from any sub-meters (e.g. 'Data are collected through the BMS')

☐ Analysis of the reliability of any sub-meters, and an estimate of the effort that might be required to improve their reliability

☐ Analysis of the reliability of any sub-meter data collection system

- ☐ If sub-meters do not exist or are deemed to be inadequate, a preliminary identification of what sub-metering must be installed and where

Undertaking the above activities will help the M&V practitioner determine the M&V approach.

3.3 Determine the M&V approach

✓	M&V Practitioner	Energy service provider	Energy user	Project sponsor
☐	Determine the M&V approach			

In determining the M&V approach, an M&V practitioner decides where to draw the measurement boundary in relation to the upgraded equipment.

M&V may be undertaken using the site utility meters, with the measurement boundary being around the whole site (IPMVP option C). This may reduce the cost of M&V but also reduces accuracy. This approach can also make it difficult to account for changes onsite that may affect energy use.

Alternatively, the measurement boundary can be set to only encompass the equipment subject to the EEM. In this case, sub-meters are used. If sub-meters do not already exist at the site, sufficient time is required to collect enough data to develop a baseline after the sub-meters have been installed but before the EEM is installed.

Determining what constitutes a full operating cycle can be challenging if energy use is not dependent on the weather. For example, there might be a clear weekly pattern such that production is an independent variable and the site is closed or operates at reduced capacity over the weekend. Yet, in some weeks production may be higher than other weeks, with no discernible reason or pattern. In this case, the baseline period should encompass periods over which production is expected to be highest, and lowest, noting that this could be well under the 12 months that would be required if weather is an independent variable.

If sub-meters already exist, the reliability of these meters, and the reliability of the data collection process, should also be determined. If existing sub-meter data or collection processes are unreliable, this must be addressed, and enough time must be allowed to collect reliable data that enables a baseline to be developed.

Check that the following has been considered when determining the M&V approach:

- ☐ Required accuracy with which savings are to be determined
- ☐ Availability of data about energy and potential independent variables
- ☐ Extent to which changes occur, and are expected to occur, that will impact on energy usage
- ☐ Time available to collect enough data to develop a baseline covering a full operating cycle
- ☐ Ability to delay the project to enable collection of sufficient baseline data when metering equipment is to be installed
- ☐ Available data and its quality
- ☐ Available M&V budget

Module 2 provides detailed guidance on determining the M&V approach.

> When energy use shows little variation over a year, and suitable independent variables cannot be identified, it may be acceptable to use an estimate of the mean energy usage. Such an estimate must cover a period long enough to determine that there is only small variation in energy use over time. Typically, over one year.

3.4 Have an M&V meeting to finalise responsibilities and budget

✓	M&V Practitioner	Energy service provider	Energy user	Project sponsor
☐	Have an M&V meeting to finalise responsibilities and budget			

Once the general approach to M&V has been decided on, a meeting should be held with all parties (M&V practitioner, energy service provider, energy user, project sponsor) to finalise agreement on M&V activities, responsibilities, and the estimated budget.

Check that key decisions have been made and documented at this meeting:

- ☐ What data must be collected (noting that new data may need to be recorded, or existing data recorded in a different way)
- ☐ What sub-metering – including meter data collection system, if any, needs to be installed or upgraded
- ☐ If sub-metering is to be installed, collect information on:
  - Where it will be installed?
  - What will be metered?
  - When it will be installed?
  - How data will be collected and stored, and who will be responsible for this?
  - The measurement interval?
  - How metering problems will be identified (even small amounts of missing data can have a large impact on M&V costs and accuracy)?
  - The required data reliability collection standard (suggest at least 99%)?
  - How long data is to be collected to develop a baseline?
- ☐ Responsibilities for monitoring changes at the site that may impact on M&V are identified:
  - Who on the energy user side will be responsible for monitoring changes
  - What must be monitored
  - How often these changes will be communicated
- ☐ When the M&V plan will be completed by
- ☐ Who on the energy user side will sign off on acceptance of the M&V plan

- ☐ How site access permissions will be obtained to verify correct installation of the EEM
- ☐ How often savings reports will be provided and for how long
- ☐ Who will sign off on the savings reports
- ☐ What the M&V budget is
- ☐ How changes in staff across all parties will be managed over the life of the project (which could stretch into several years) to ensure all parties remain adequately informed

3.5 Collect data

✓	M&V Practitioner	Energy service provider	Energy user	Project sponsor
☐	Collect data	Collect data	Collect data	

M&V practitioners should coordinate with the energy user, and energy service provider as appropriate.

The data collection plan should be relevant to the measurement boundary and the EEM.

Check that the data collection plan covers the following required data:

- ☐ Energy consumption data. If the EEM is only going to impact on consumption of energy within the measurement boundary, you only need to collect data for that type of energy. If there are likely to be interactive effects, you may need to install additional metering to account for them
- ☐ Data on potential independent variables. Potential independent variables are measurements of parameters that routinely vary (such as average daily temperature) and are expected to influence energy use
- ☐ Data on static factors. If data are not collected, it may not be possible to determine energy savings should a static factor change

Collect data. Check that the following occurs:

- ☐ Measurement instruments are in place to collect data
- ☐ Instrument accuracy and calibration is understood, documented, and verified to be fit for purpose
- ☐ Checks are undertaken to verify reliable data collection
- ☐ Data are collected
- ☐ The reliability of data collection is tracked, and corrective action is undertaken when reliability is unacceptable:
  - ☐ Data collection software is configured to send alerts when a meter fails to upload data
  - ☐ Reports that document what time periods are missing data are created automatically
- ☐ Data is stored in a place that is readily accessible to the M&V practitioner

Insight

The biggest problem with sub-meters is reliable and consistent data collection. Manage this by setting a reliability standard that is non-negotiable and consider paying for the data instead of paying for the meter.

3.6 Analyse data

	M&V Practitioner	Energy service provider	Energy user	Project sponsor
✓ ☐	Analyse data			

The M&V practitioner undertakes data analysis.

Check that the following steps are undertaken:

- ☐ Energy and Independent variable raw data is processed into consistent time intervals (e.g. electricity interval data collected at half-hour intervals would need to be converted to daily data to align with weather data that is only available as daily measurements)
- ☐ Missing data are identified
- ☐ Missing data are dealt with; the means of dealing with missing data is documented
- ☐ The cause of missing data is substantiated and documented (e.g. meter reset, power failure)
- ☐ A regression model is developed
- ☐ The acceptability of the regression model is evaluated, and if unacceptable, other models (e.g. with different independent variables, or different time periods) are tested until an acceptable model is found
- ☐ The range of the model is identified
- ☐ The model is tested (optional, but strongly recommended). Test the model against other periods to detect any unidentified factors that may cause significant variation in energy use between years. If this is the case, consider narrowing the measurement boundary

These steps are detailed in chapter 1 of module 2.

3.7 Assess if the energy model if acceptable

	M&V Practitioner	Energy service provider	Energy user	Project sponsor
✓ ☐	Is the energy model acceptable?			

Verify that the model is acceptable:

- ☐ It satisfies the statistical tests described in chapter 1 of module 2
- ☐ The modelling error is sufficiently low that it will be possible to determine the savings with an acceptable level of uncertainty (there is always an element of error or uncertainty in a regression model)

If it is not possible to build an acceptable energy model, then it may be necessary to completely change the M&V approach. For example, rather than rely on site-wide utility meters it may be necessary to install sub-meters just around the equipment subject to the EEM. (It is generally only possible to do this after assessing the baseline. By the time you get to the operating period, it is too late!)

3.8 Complete the M&V plan

	M&V Practitioner	Energy service provider	Energy user	Project sponsor
✓ ☐	Complete the M&V plan			

Completing the M&V plan involves ensuring that the requirements of EVO 10000 – 1:2022, IPMVP Core Concepts 2022, chapter 13, are met. At a minimum, check that the M&V plan covers the following:

- ☐ Facility and project overview
- ☐ EEM intent
- ☐ Selected IPMVP option and measurement boundary
- ☐ Baseline: period, usage, and conditions
- ☐ Reporting period
- ☐ Basis for adjustment
- ☐ Calculation method and analysis procedure
- ☐ Energy prices
- ☐ Meter specifications
- ☐ Data collection and monitoring responsibilities
- ☐ Expected uncertainty
- ☐ M&V savings reporting budget
- ☐ M&V savings report template

☐ Quality assurance

This is also a good time to double-check that data collection from any sub-metering is ongoing and reliable.

3.9 Present the M&V plan and agree on reporting responsibilities

✓	M&V Practitioner	Energy service provider	Energy user	Project sponsor
☐	Present the M&V plan and agree on reporting responsibilities			

The completed M&V plan should be presented by the M&V practitioners to the energy service provider, energy user, and project sponsor.

Check that the meeting covers the following:

☐ Presentation of the plan, focusing on:

- The boundary and IPMVP option selection
- Data issues and how these have been resolved
- The baseline model, showing predicted and actual energy use, and how well the model predicts energy use in non-modelled periods of the baseline
- Expected uncertainty of savings determination
- Static factors
- Agreement on the format and contents of M&V savings reports

☐ Agreement on ongoing responsibilities for:

- Energy data collection
- Independent variable data collection
- Static factor data collection
- Notifications of changes to the site that may impact on energy usage
- Frequency of provision of savings reports

Note: Developing an M&V plan in adherence with the IPMVP requires that these responsibilities be spelled out in the M&V plan.

☐ Agreement on the timeline for M&V plan approval and quality assurance

Communication is key in M&V.

3.10 Approve the M&V plan (including Quality Assurance)

	M&V Practitioner	Energy service provider	Energy user	Project sponsor
✓ ☐			Approve the M&V plan (including QA)	Approve the M&V plan (including QA)

The energy user and the project sponsor must approve the plan. IPMVP recommends that an independent third-party verifier, who is both an expert in M&V and in the proposed EEM(s), undertake a review of the plan.

Check the following:

- ☐ M&V plan has been reviewed by an independent expert
- ☐ M&V plan is approved

3.11 Verify correct EEM operation

	M&V Practitioner	Energy service provider	Energy user	Project sponsor
✓ ☐	Verify correct EEM operation		Monitor site for changes	

After implementation of the EEM its correct operation must be verified.

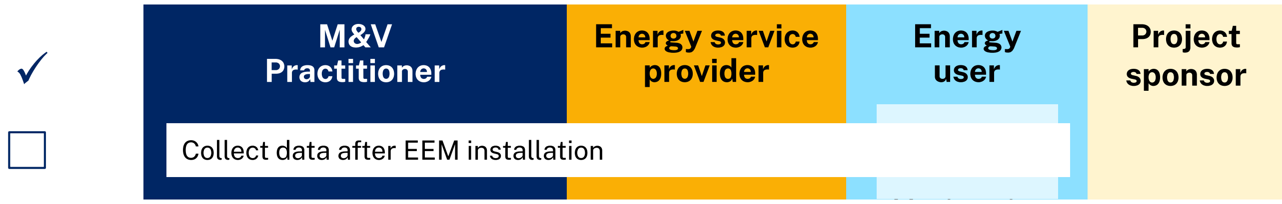
Check that the following has been undertaken:

- ☐ A site visit to physically inspect the new equipment and, if needed, take spot measurements to verify correct operation
- ☐ Analysis of preliminary data to see if energy use and savings are as expected

Where there are deficiencies with the operation of the EEM, steps must be taken:

- ☐ Listing the deficiencies and advise the energy user and energy service provider of them
- ☐ Undertake another site inspection when advised that deficiencies have been rectified to confirm this

3.12 Collect data after EEM installation



After installing the EEM, data must be collected to enable the development of M&V savings reports. Data collection systems must be designed, and data collection monitored to minimise the likelihood of missing energy or independent variable data.

There should be regular contact with the site to ensure changes that may impact on energy use within the measurement boundary are detected. Records should be kept of any changes.

Check the following:

- ☐ Energy user has been contacted once a quarter during the reporting period to discuss performance of the EEM and see if there are any changes that may impact on energy use within the measurement boundary
- ☐ Data are routinely analysed (at least quarterly) to identify deficiencies or unexpected energy use

3.13 Determine savings

Check that savings have been determined:

- ☐ Identify the period over which savings are to be reported
- ☐ Determine the basis on which savings will be calculated
- ☐ Ensure that necessary non-routine adjustments have been undertaken[4] to account for unexpected changes at the site, unrelated to the EEM, that may cause energy use to increase or decrease
- ☐ Identify the intervals for which savings cannot be determined
- ☐ Calculate the savings
- ☐ Determine the uncertainty in the savings
- ☐ Verify that the savings are more than twice the standard error in the model (IPMVP sets out that the savings must be twice the standard error for use of a model to be valid)
- ☐ State the savings along with the uncertainty at the desired confidence level

4 Under state and federal white certificate schemes, non-routine adjustments may only be permissible if specified conditions are met.

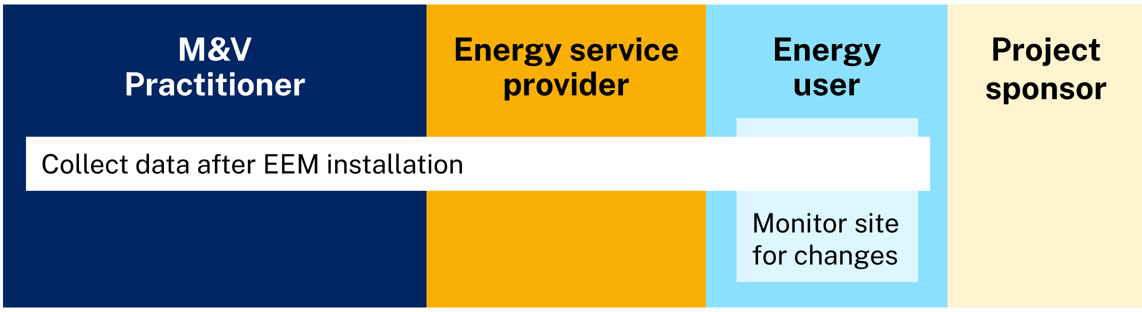
3.14 Develop savings reports

Savings reports should be developed in adherence with the reporting requirements described in chapter 13 of IPMVP Core Concepts 2022.

Check that each savings report has the required sections:

- ☐ Overview of the M&V savings report
- ☐ Project background
- ☐ M&V data collection activities during current reporting period
- ☐ Savings calculations and methodology
- ☐ Verified savings
- ☐ Additional information required

3.15 Monitor site for changes that impact on savings or the determination of savings



The site should be monitored for as long as necessary to produce savings reports or verify that the EEM is operating and performing as intended.

Check that monitoring activities include key actions:

- ☐ Track ongoing savings. A graph of cumulative savings, which should show cumulative savings increasing over time, is an effective way of doing this and of communicating the savings provided by the EEM(s)
- ☐ Monitor changes to static factors (i.e. non-routine events)

3.16 Debrief and apply the learnings to future energy efficiency projects

M&V Practitioner ✓	Energy service provider	Energy user	Project sponsor

☐ Debrief and apply the learnings to future energy efficiency projects

When M&V activities have concluded, a debriefing meeting can yield insights that can be useful to all parties in future projects.

Check that a debriefing meeting has covered the following items:

☐ Were the savings as expected? If not, what could be done differently in the future to ensure better savings estimates or better performance of the EEM?

☐ What benefits did M&V provide? Benefits could be:

- increased savings, due to verification and monitoring activities identifying problems that otherwise may not have been detected or may not have been detected as quickly
- improved understanding of how the site uses energy, leading to identification of additional savings opportunities
- access to financing or government-enabled incentives

☐ What would we do differently if we were doing this again?

4 Deficiencies in M&V practice and how to avoid them

M&V can be complex in nature. As highlighted in chapter 2 of module 1, issues that may arise due to actions or omissions by the energy user, the M&V practitioner or the energy service provider are predominantly due to a lack of planning, communication, or capacity to verify and monitor performance. Table 3 lists some common deficiencies and how to avoid them.

Table 3 Common M&V deficiencies and how to avoid them

Deficiency	Possible consequences of the deficiency	Why the deficiency occurs	How to avoid it
Interest only in creating ESCs or VEECs in fast and inexpensive ways, and not in maintaining ongoing performance of the EEM and savings	• The wrong IPMVP M&V option is chosen (with much less certainty of savings – often option C when option B would have been better) • Energy savings are not sustained into the future, leading to financial losses and loss in greenhouse gas savings	• A short-term focus on immediate financial benefit • Lack of understanding of the benefits of ongoing M&V • Low M&V budgets	Follow the process for M&V outlined in this guide, with a focus on the whole operating life of the EEM
Overconfidence in the EEM savings estimate	• The wrong IPMVP M&V option is chosen • Estimated savings are highly uncertain • Savings are low or absent compared to initial estimates	• M&V practitioner has no expertise in the EEM being deployed and is unable to critique savings estimates • Inadequate site assessment by energy service provider • Lack of risk assessment by both the energy service provider and the energy user	• Verify the expertise of the energy service provider with this EEM (e.g. experience with deploying the EEM elsewhere, savings delivered from those projects) • Ensure that the first steps of the process outlined in this guide are not skipped (including site visits) • Favour the use of submetering when planning for M&V rather than relying only on the utility meters

continues

Table 3 *continued*

Deficiency	Possible consequences of the deficiency	Why the deficiency occurs	How to avoid it
Poor communication and lack of proper engagement between the different M&V parties	• Energy models are difficult to design because of a lack of data and/or site information • Significant delays occur in completing the M&V and determining the energy savings • Risk of not accessing white certificate schemes arises	• Low M&V budgets • A focus on only getting the EEM installed and not on maintenance of savings through proper M&V • The energy user has no time to engage in the M&V process	At the start of the M&V process, all parties involved should: • put effort into understanding and communicating the value of M&V and the consequences of inadequate M&V budgets • focus on the desired outcome of the project: sustained and reliable energy savings • maintain direct channels of communication with each other • clearly understand that the interest and involvement of the energy user is essential
Inadequate verification/ commissioning of the EEM	• EEM fails to function as expected • Savings are less than expected or are zero, or energy use actually increases	• The implementation budget is insufficient to correctly commission the EEM installation • Verification is not scheduled or budgeted for as part of M&V	• Allocate a budget just for verification and commissioning • Focus on the desired outcome of the project – sustained, reliable, energy savings

continues

Table 3 *continued*

Deficiency	Possible consequences of the deficiency	Why the deficiency occurs	How to avoid it
Assuming EEMs always perform perfectly (no monitoring undertaken)	Savings are not sustained over time	• Inexperience with energy efficiency projects • A focus on getting the EEM installed, rather than on the lifetime savings the M&V delivers	• Set up a monitoring procedure to regularly review EEM performance • Produce regular M&V savings reports
Not anticipating changes that may affect the EEM or M&V	Savings cannot be determined with confidence	• Lack of understanding of the site and future plans for the site • Insufficient communication between the energy user and M&V practitioner	• Thoroughly understand the EEM and how it saves energy, and how site changes may affect savings • Favour the use of submetering for M&V rather than relying on utility meters • Put in place a procedure for communicating changes on site; schedule regular discussions

Table 3 *continued*

Deficiency	Possible consequences of the deficiency	Why the deficiency occurs	How to avoid it
No monitoring of changes to static factors that may make identifying savings harder	• Uncertainty in savings estimate is high • Savings cannot be determined	• Lack of awareness of the energy user about the need to monitor static factors • Changes in the personnel responsible for overseeing the M&V process	• Understand that M&V relies on the energy user to monitor and communicate static factor changes • Put in place a procedure for monitoring changes • When personnel change (either on the side of the energy user, or the M&V practitioner), arrange to meet and review the project • Arrange quarterly meetings or calls between energy user and the M&V practitioner
Poor data collection in the reporting period	• Uncertainty in savings estimate is high • Savings cannot be determined	• An assumption that data collection systems are reliable • No alerts configured to advise of data outages • Not enough time allocated to monitoring data quality/react to alerts	• Assume data collection systems cannot be relied on (failure of data collection systems, especially submeters, is a common problem) • Have a reliability service agreement with the data collection system provider; consider paying for the data, not for the meter • Put in an alert system for data outages • Budget and schedule time to monitor for outages and to take corrective action

Acronyms and definitions

ACCUs (Australian carbon credit units): a tradable product – similar to a white certificate – that can be created in the ERF.

ACP (accredited certificate provider): an entity accredited to create certificates in the New South Wales Energy Security Safeguard (including the Energy Savings Scheme and the Peak Demand Reduction Scheme).

Adjusted R2 (adjusted coefficient of determination): a statistical measure of the extent to which variations in the energy consumption are explained by an energy model, allowing for the number of independent variables used in the model.

AP (accredited person): an entity accredited to create certificates in the VEU program.

Baseline: the period before the EEM is implemented that is used to determine energy usage before implementation of the EEM. The baseline period must be long enough to cover one complete operating cycle of the upgraded system, from maximum energy consumption and demand to minimum.

CDD (cooling degree day): used to assess how hot a climate is over a period – a day, week, month or year. A CDD references a 'balance point'. When the average daily temperature is above the balance point, the number of CDDs is the difference between the average temperature and the balance point.

With a balance point of 18 degrees Celsius:

- If today's average temperature is 20°C, then there are 2 CDDs (i.e. 20 – 18°C).
- If today's average temperature is 16°C, then there are zero CDDs, because it is not possible to have negative CDDs.

The number of CDDs in a month is the sum of the CDDs across all days in the month.

The number of CDDs is very commonly used as an independent variable in regression models for buildings in which HVAC energy use is a significant proportion of total energy use. This includes most commercial buildings. See also HDD.

Collinearity: occurs when the value of one of the independent variables can be highly accurately predicted by other independent variables in the regression model. It is strongly recommended that collinearity be avoided.

CV_{RMSE} (coefficient of variation of the root mean squared error): the standard error of an energy model expressed as a percentage of the average energy consumption.

Dependent variable: the value of y in a regression model. For M&V, this is usually the energy consumption.

ECM (energy conservation measure): a term used in earlier versions of the IPMVP guidelines. It has been replaced by energy efficiency measure (EEM).

EEM (energy efficiency measure): a project implemented to reduce energy usage.

Effective range: the range of independent variable values over which an energy model is deemed valid, in the context of the PIAM&V method.

- The PBA M&V method uses **eligible range** to describe this concept. The 2 distinct processes used to determine the PIAM&V method effective range and the PBA M&V method eligible range are detailed in the first section of module 2.
- The PBA M&V method defines the effective range as the range of the independent variable values over a measurement period.

The terms effective range and eligible range have specific meanings in PIAM&V and PBA M&V, which do not necessarily align with the IPMVP term range.

Energy service provider: the entity responsible for specifying and installing the EEM.

Energy user: the owner of the site where the EEM is being implemented. May also refer to the individual employed by the energy user who is responsible for energy efficiency improvements (e.g. a facility manager). Also known as the energy consumer under the VEU program.

EPC (energy performance contract): a contract in which an energy service provider guarantees the savings from EEMs, and agrees to cover the cost of any shortfall in savings.

ERF (Emissions Reduction Fund): a scheme administered by the federal Clean Energy Regulator, enabling the Australian Government to purchase emissions reductions.

ESC (Energy Savings Certificate): a tradable white certificate created in the Energy Savings Scheme.

ESCO (energy services company): a company that develops, designs, builds, and finances projects that save energy and reduce energy costs.

ESS (NSW Energy Savings Scheme): a white certificate scheme administered by the Independent Pricing and Regulatory Tribunal.

EVO® (Efficiency Valuation Organization): the publisher of the IPMVP.

HDD (heating degree day): a measure used to assess how cold a climate is over a period – a day, week, month or year. An HDD references a 'balance point'. When the average daily temperature is below this balance point, the number of HDDs is the difference between the balance point and the average temperature. For example, with a balance point of 18°C:

- If today's average temperature is 16°C, then there are 2 HDDs (i.e. 18 – 16°C).
- If today's average temperature is 20°C, then there are zero HDDs, because it is not possible to have negative HDDs.

The number of HDDs in a month is the sum of the HDDs across all days in the month.

Like CDDs, HDDs are very commonly used as an independent variable in regression models for buildings in which HVAC energy use is a significant proportion of total energy use. This includes most commercial buildings.

HVAC (heating, ventilation and air conditioning): a system that is used to provide comfortable temperatures inside a building by providing heating and/or cooling, in addition to ventilating the building.

ICER (industrial and commercial emissions reduction): a method in the ERF that uses M&V to create ACCUs.

Implementation: a term used in the ESS and VEU in place of the term energy efficiency measure (EEM).

Independent variable: a parameter that routinely varies (such as the weather), which must satisfy the following 5 conditions:

- It can be reasonably expected to influence energy use within the measurement boundary, because there is an engineering or scientific explanation as to why energy use will change when the independent variable changes.
- Using regression analysis, it can be shown that the amount of energy used within the measurement boundary is related to changes in the independent variable – this should be visible on a scatter plot.
- The strength of the statistical correlation with energy use is such that the absolute value of the variable's t-statistic in a regression is equal to 2 or more.
- The variable does not demonstrate collinearity with any other independent variable used in the regression model.
  - Microsoft Excel's® LINEST function tests for collinearity; the coefficient of the independent variable will be zero if there is collinearity. Variables that demonstrate collinearity with one or more variables must be excluded from regression models.
- The independent variable is independent of the EEM and does not change because of the EEM. For example, the flow rate in a compressed air system cannot be used as an independent variable to measure air leakage.

Interactive effects: occur when an EEM causes a change in energy use outside the EEM's measurement boundary.

Example: A lighting upgrade is undertaken, using IPMVP option B: retrofit isolation. The new lights consume less energy than the old lights. The decrease in lighting energy has the following interactive effects on the HVAC system:

- More energy is needed to heat the building because less heat is provided by the lighting.
- Less energy is needed to cool the building because less heat is provided by the lighting.

IPMVP® (International Performance Measurement and Verification Protocol): owned and maintained by EVO, the IPMVP is used globally for the determination of savings. At the time of writing, the latest version of the protocol is IPMVP Core Concepts, March 2022, EVO10000 – 1:2022.

M&V practitioner: the person undertaking the M&V process for an energy efficiency project.

Measurement boundary: the boundary of what is measured by meters and instruments that record energy use and the independent variables. The boundary is either drawn around the whole site, using utility energy meters, or around the equipment subject to the EEM, using sub-meters (Figure 5).

IPMVP offers 4 options for determining energy savings (options A, B, C, and D), depending on where the measurement boundary is drawn (Table 4).

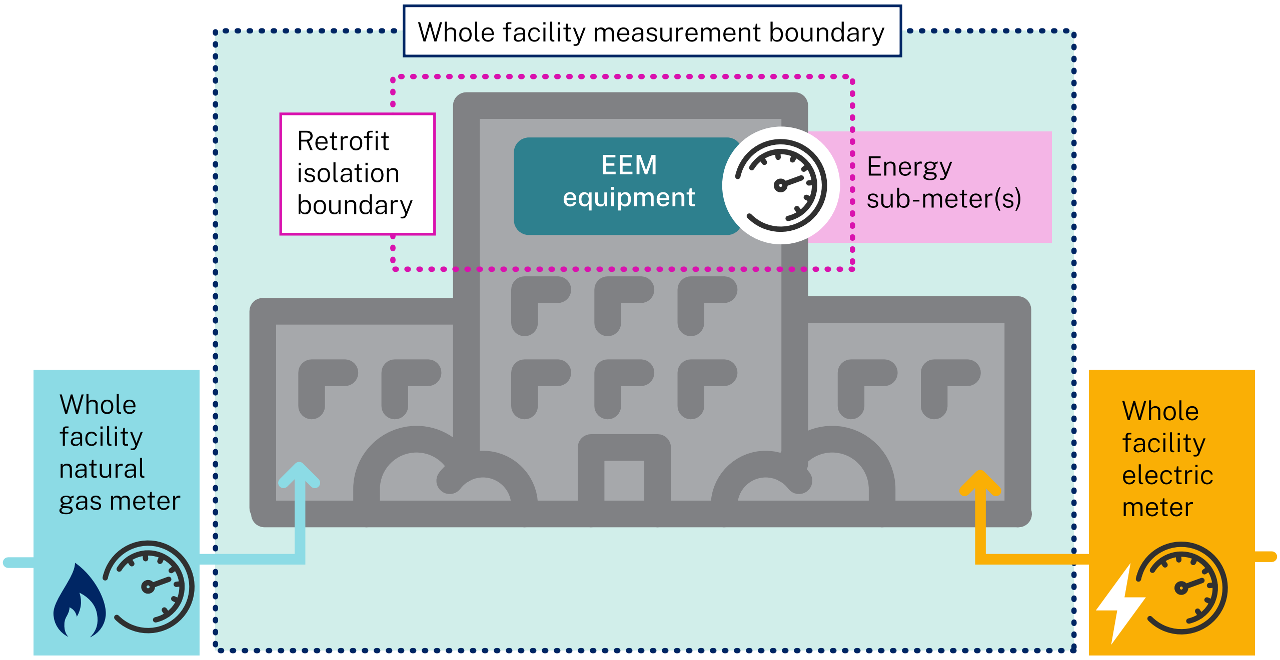


Figure 5 Examples of measurement boundaries (from IPMVP Core Concepts 2022)

Table 4 IPMVP Options

IPMVP option	How savings are calculated	Typical application
A. Retrofit isolation: Key parameter measurement	Engineering estimate of baseline and reporting period energy from short-term or continuous measurements of key parameter(s) and estimated values.	Replacing lights with more efficient lights – the power draw (kW) of the lights is the key parameter and operating hours are estimated.
B. Retrofit isolation: All parameters measurement	Short-term or continuous measurements of baseline and reporting period energy, or engineering estimates using measurements of proxies of energy consumption.	Application of a variable-speed drive and controls to a motor to adjust pump flow.
C. Whole facility	Analysis of the whole facility baseline and reporting period meter (utility) data.	Multifaceted energy management programs affecting many systems in a facility.
D. Calibrated simulation	Energy consumption simulation, calibrated with hourly or monthly utility billing data. Energy end-use metered performance data may be used in model refinement.	Multifaceted energy management programs affecting many systems in a facility, but with no metering existing during the baseline period.

NRA (non-routine adjustment): an adjustment made when determining energy savings to account for a non-routine event.

NRE (non-routine event): an unexpected change that causes energy use within the measurement boundary to change in a way that cannot be accounted for by the regression model.

Operating period: a term used in the ESS and VEU in place of the term reporting period.

PBA M&V (Project Based Activities – Measurement and Verification): the method in the VEU program through which an AP can undertake the M&V process to create VEECs.

PIAM&V (Project Impact Assessment with Measurement and Verification): the method in the ESS through which an ACP can undertake the M&V process to create ESCs.

Project sponsor: anyone responsible for getting capital expenditure for a project approved (e.g. executive management, finance department, financial institution).

Range (of independent variable): the range of values of an independent variable, from lowest to highest, as used in a regression model.

Regression model: more correctly called a (multiple) linear regression model, is a mathematical model of the form $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + \ldots + b_nX_n$ where Y is the dependent variable; X_1, X_2, X_3 ... X_n are independent variables; and b_0, b_1, b_2, b_3 ... b_n are constants.

Relative precision (of energy savings): a term used in the PIAM&V and PBA M&V methods in place of the term uncertainty; expressed as a percentage of the energy savings.

Reporting period: is the measurement period following the implementation of EEM. The reporting period needs to be long enough to cover one complete operating cycle, from maximum energy consumption and demand to minimum.

Site constant: a term used in the ESS and VEU in place of the term static factor.

Static factor: a factor that is likely to impact the energy use within the measurement boundary, but is not expected to vary. Should it change significantly in a way that is not expected, this change would need to be taken into consideration.

The square meters of occupied space of a school with a stable student population, which the principal says is unlikely to change, would be a static factor. If the school added extra portable classrooms, increasing the occupied space and energy use, a project using IPMVP option C would need to take this into consideration when determining energy savings using M&V.

t-statistic: a statistical test used to verify the accuracy and significance of the estimated relationship between an independent variable and energy consumption for an energy model.

Uncertainty: represents the range in which the true value is likely to lie, at a given confidence level – for example, savings ± uncertainty, at confidence level. Uncertainty may be expressed as a value or as a percentage. Uncertainty may also be referred to as 'error'.

Example:

Energy savings = 100 MWh ± 5 MWh, at a 90% confidence level.

VEEC (Victorian Energy Efficiency Certificate): a tradable white certificate created in the VEU program.

VEU (Victorian Energy Upgrades) program: a white certificate program administered by the Victorian Essential Services Commission.

White certificate: a tradable commodity that either represents a certain amount of energy savings – typically 1 MWh – or a certain amount of greenhouse gas emission savings – typically 1 tonne CO_2-e.

In a white certificate scheme, a government requires each energy retailer to surrender to the government each year a certain number of white certificates. The certificates are created through energy efficiency projects, with the number of certificates from any given project determined through a methodology defined by the government.

The ESCs and VEECs are examples of white certificates that are defined by the ESS and VEU respectively.

Comparison of IPMVP, PIAM&V and PBA M&V terminology

The terminology varies between IPMVP, ESS and VEU. An understanding of which terms are equivalent is useful (Table 5).

Table 5 Comparison of IPMVP, ESS and VEU terminology

IPMVP term	ESS: PIAM&V term	VEU: PBA M&V term
EEM (energy efficiency measure)	Implementation	Implementation
Interactive effects	Interactive effects	Interactive savings
Reporting period	Operating period	Operating period (forward creation) Reporting period (annual creation)
Static factor	Site constant	Site constant
Uncertainty of savings (as a percentage)	Relative precision (as a percentage)	Relative precision (as a percentage)
Range	Effective range[a]	Effective range, eligible range[a]

a The terms effective range and eligible range have specific meanings in PIAM&V and PBA M&V, which do not necessarily align with the IPMVP term range.

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