

# Calculating Savings using Measurement and Verification

Non-mandatory manual for participants in the  
Victorian Energy Upgrades program



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Throughout the document, a warning symbol  has been inserted to refer readers to key steps that require interaction with the ESC. In these steps, the reader should refer to their publications. The ESC administrative processes and requirements for project-based activities, including Measurement and Verification, are available on the ESC VEET website: [www.veet.vic.gov.au](http://www.veet.vic.gov.au).

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# 1 Introduction to Measurement and Verification

Measurement and Verification (M&V) is a method used to measure energy and greenhouse gas savings from a project. The Victorian Energy Efficiency Target (VEET) (Project-Based Activities) Regulations 2017 allow for M&V to be used to measure project savings and award Victorian Energy Efficiency Certificates (VEECs) for custom upgrades projects.

Sections 1 and 8 of this document may provide a useful overview for readers familiar with the principles of M&V, but less familiar with their application in Victorian Energy Upgrades.

## 1.1.1 Reference Documents

There are several useful documents available that describe M&V principles and help practitioners develop and implement M&V plans. These documents are outlined in Table 1 and Table 2 and will be referenced throughout the document.

Table 3 includes other useful reading materials, which can support the application of M&V methods (for example, brief statistics guides). These are not essential to understand the method, but would be useful for readers wishing to understand the application of M&V in more detail.

## 1.1 Using This Document

This document is a reference to the method of M&V in the Victorian Energy Upgrades program, which is used to create VEECs for project-based activities (where 1 VEEC = 1 tonne of CO<sub>2</sub>-equivalent savings). Project-based activities are technology neutral and can be used for custom upgrades where “off the shelf” activities are not appropriate.

This document focuses on the practical implementation of M&V in Victorian Energy Upgrades. It is not a complete guide to undertaking M&V, but will introduce key concepts and refer to external documents for further detail.

A complementary *Victorian Energy Upgrades M&V Workbook* steps through the Victorian Energy Upgrades M&V calculations and sets out typical calculations for an M&V project in an easily followed format. Each of these is referenced throughout this document.

Section 1 of this document gives an overview of M&V and how it is used in Victorian Energy Upgrades, and where to go for more information.

Sections 2 - 7 introduce key M&V concepts, how they interact in Victorian Energy Upgrades and the workbook, and give examples and further references.

Section 8 summarises the methods and variables to estimate energy savings and VEECs for a project and provides example calculations.



**Table 1: Key M&V reference documents – Victorian Energy Upgrades Program**

Document name	Purpose	Our reference
Program documents - mandatory		
Victorian Energy Efficiency Target (Project-Based Activities) Regulations 2017	Sets out the regulations for the M&V method	<i>VEET PBA Regulations</i>
Department of Environment, Land, Water and Planning (2017) <i>Measurement and Verification in the Victorian Energy Efficiency Target scheme: Methods and Variables</i>	Sets out the methods and variables that must be used for M&V savings calculations in the VEET scheme	<i>DELWP M&amp;V Methods and Variables</i>
Essential Services Commission (2017) <i>Explanatory Note - Project-Based Activities: Measurement and Verification Part 1: Activity Guidance</i>	Provides important information about participants' obligations when undertaking M&V projects in Victorian Energy Upgrades	<i>ESC Activity Guidance</i>
Essential Services Commission (2017) <i>Explanatory Note - Project-Based Activities: Measurement and Verification Part 2: Compliance Requirements</i>	Guides interested stakeholders through the compliance requirements for M&V projects in Victorian Energy Upgrades	<i>ESC Compliance</i>
Program documents – non-mandatory		
<i>Victorian Energy Upgrades M&amp;V Workbook</i>	Calculation tool for Victorian Energy Upgrades M&V projects	<i>Victorian Energy Upgrades M&amp;V Workbook</i>

**Table 2: Other M&V reference documents – External Documents**

Document name	Purpose	Our reference
Efficiency Valuation Organisation (2016) <i>International Performance Measurement and Verification Protocol: Core Concepts</i>	Standard principles and terms for M&V processes	<i>EVO IPMVP Core Concepts</i>
Efficiency Valuation Organisation (2012) <i>International Performance Measurement and Verification Protocol: Volume I - Concepts and Options for Determining Energy and Water Savings</i>	Framework to determine energy and water savings resulting from the implementation of an energy efficiency program	<i>EVO IPMVP Concepts and Options</i>
US Department of Energy (2015) <i>M&amp;V Guidelines: Measurement and Verification for Performance-based Contracts version 4.0</i> : Prepared for the Federal Energy Management Program	Detailed procedures and guidance for developing and implementing M&V plans	<i>DoE FEMP Guidelines</i>
NSW Independent Pricing and Regulatory Tribunal (2016) <i>Method Guide: Project Impact Assessment with Measurement and Verification Method</i>	Detailed guidance on implementation of M&V in NSW Energy Savings Scheme	<i>IPART PIAM&amp;V Method Guide</i>
NSW Office of Environment and Heritage (2012) <i>Measurement and Verification Operational Guide: Best Practice M&amp;V Processes</i>	Guide for developing and implementing M&V plans	<i>OEH M&amp;V Guide: Best Practice Processes</i>
NSW Office of Environment and Heritage (2012) <i>Measurement and Verification Operational Guide: Application specific guidebooks</i>	Guidebooks on planning and conducting M&V for specific technologies	<i>OEH M&amp;V Guide: Applications</i>

#### 4 Calculating Savings using Measurement and Verification

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**Table 3: Other useful reference documents – External Documents**

Document name	Purpose
Efficiency Valuation Organisation (2014) <i>Statistics and Uncertainty for IPMVP</i>	Describes how statistics can be used to measure uncertainty in M&V.
Mackenzie, A (2005). <i>Mathematics and Statistics for Life Scientists – Section C2 Presenting Data</i>	Aims to improve mathematical and statistical skills of readers.
Frost, J (2015). “The Danger of Overfitting Regression Models”, <i>Minitab Blog</i> , <a href="http://blog.minitab.com/blog/adventures-in-statistics-2/the-danger-of-overfitting-regression-models">http://blog.minitab.com/blog/adventures-in-statistics-2/the-danger-of-overfitting-regression-models</a>	Describes how to detect and avoid an overfit regression model.
Origin Lab. “Regression and Curve Fitting - Residual Plot Analysis”, <i>Origin Help</i> , <a href="http://originlab.com/doc/Origin-Help/Residual-Plot-Analysis">originlab.com/doc/Origin-Help/Residual-Plot-Analysis</a>	Guide to calculate the quality of regression models through residual plots.
Australian Government (2013) <i>Energy Efficiency Opportunities Energy Savings Measurement Guide</i>	Technical document which helps estimate, measure, evaluate and track energy efficiency savings.
US Food and Drug Administration (2013). <i>ORA Laboratory Manual: Section 4 Basic Statistics and Data Presentation</i> , <a href="https://www.fda.gov/ScienceResearch/FieldScience/LaboratoryManual/">https://www.fda.gov/ScienceResearch/FieldScience/LaboratoryManual/</a>	General guide on statistics application, data presentation and verification.
Department of Industry (2012), <i>NatHERS climate files 2012</i> , available from NIWA, <a href="https://www.niwa.co.nz/node/109982">https://www.niwa.co.nz/node/109982</a>	Files developed by the Commonwealth of Australia compiling Bureau of Meteorology raw climate data to complete a typical year for every climate zone in Australia.
Exemplary Energy Hourly Data and ERM data (available for purchase through ACADS-BSG), <a href="mailto:members.ozemail.com.au/~acadsbsg/">members.ozemail.com.au/~acadsbsg/</a>	Hourly weather data for use in air conditioning load estimation, building energy analysis and HVAC applications.
Bureau of Meteorology, <i>Average annual &amp; monthly heating and cooling degree days – How are the Values Calculated?</i> <a href="http://bom.gov.au/jsp/ncc/climate_averages/degree-days/index.jsp">bom.gov.au/jsp/ncc/climate_averages/degree-days/index.jsp</a>	Describes how the number of heating and cooling degrees day can be calculated for a data set.

## 1.2 What is M&V?

M&V is a transparent, rules-based method to determine the energy savings obtained by an energy management program.

M&V of a project in Victorian Energy Upgrades involves following a clear process to define and measure project savings. The process occurs in five stages:

- Accreditation
- Identify the Scope
- Project Plan
- Undertake Work
- Report

Each stage in the process involves a number of M&V steps, and all stages except “undertake work” require interaction with the Essential Services Commission (ESC). After the process is complete you may create VEECs from the project.

The M&V process in Victorian Energy Upgrades is shown in Figure 1.

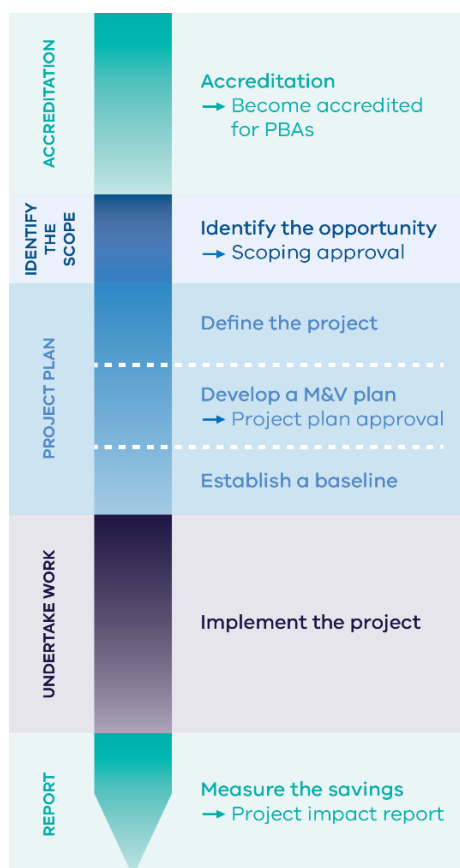


Figure 1: M&V process

### 1.2.1 Accreditation

**Accreditation:** You must be accredited by the ESC to create VEECs using M&V.

⚠ **Apply for accreditation**

### 1.2.2 Identify the Scope

**Identify the opportunity:** Identify an energy savings project (e.g. from an energy audit). This step happens before M&V planning can commence.

⚠ **Apply for scoping approval:** The output of this step in Victorian Energy Upgrades is to seek scoping approval for the project from the ESC.

### 1.2.3 Project Plan

**Define the project:** Decide what needs to be measured, and for how long (see sections [2 Energy Sources](#), [4 Measurement Boundary](#), [5 Measurements](#), [7 Parameters](#)).

**Develop an M&V plan:** Set out the general M&V approach, including details of the baseline conditions, what will be measured, how it will be measured, and how savings will be calculated (see sections [2 Energy Sources](#), [3 Baseline, Operating, and Reporting Periods](#), [5 Measurements](#), [6 Energy Models](#)).

⚠ **Apply for project plan approval:** The output of these steps in Victorian Energy Upgrades is to seek project plan approval for the project from the ESC.

**Establish a baseline:** Gather energy consumption data before the project is implemented, and develop a model to explain how energy is used within the project boundary (see sections [3 Baseline, Operating, and Reporting Periods](#), [5 Measurements](#)).

### 1.2.4 Undertake Work

**Implement the project:** Install the energy savings equipment or modifications.

⚠ **Approval from the ESC required:** Before work is undertaken, the project must have scoping approved and a project plan submitted.

### 1.2.5 Report

**Measure the savings:** Measure the energy consumption, develop a model and calculate how much energy and greenhouse gas emissions were saved by the project (see [5 Measurements](#), [6 Energy Models](#), [7 Parameters](#), [8 Equations](#)).

**⚠ Submit project impact report:** The output of this step in Victorian Energy Upgrades is to submit a project impact report for approval by the ESC.

The average processing times for these administrative steps can be found in the ESC's website<sup>1</sup>.

### 1.2.6 Further Reading

#### Program Resources

- *ESC Activity Guidance*, Section 4 and 5
- *ESC Compliance*, Section 2

#### External Resources

- *OEH M&V Guide: Best Practice Processes*, Section 2.6
- *DoE FEMP Guidelines*, Section 2.2

## 1.3 Additional Benefits of M&V

M&V brings rigour and increased certainty to the values and risks of energy savings investments. It is designed to answer the question: “How can I be sure that I’m really saving money?”

Some of the benefits of M&V include documenting financial transactions, enhancing financing for efficiency projects, improving engineering design and facility operations and maintenance, managing energy budgets and increasing understanding of energy management with external stakeholders.

Several broad trends are helping to make M&V more accessible. Firstly, data collection costs have fallen in recent years, so more businesses are monitoring their sites using submetering and smart controls which reduces M&V costs. Secondly, the International Performance Measurement and Verification Protocol (IPMVP) published by the Efficiency Valuation Organisation (EVO) has defined a standard approach to M&V. Many professionals in Australia are now trained and certified in the discipline of M&V, improving market confidence and access to M&V for projects of all sizes.

### 1.3.1 Further Reading

#### Program Resources

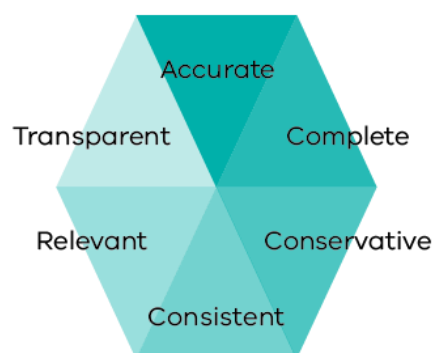
- *ESC Activity Guidance*, Section 4
- *ESC Compliance*, Section 2

#### External Resources

- *EVO IPMVP Concepts and Options*, Section 2.1
- *OEH M&V Guide: Best Practice Processes*, Section 1

## 1.4 IPMVP Principles

The International Performance Measurement and Verification Protocol (IPMVP) defines six fundamental principles for M&V. The method must be: Accurate, Complete, Conservative, Consistent, Relevant, and Transparent.



**Figure 2: Principles of M&V**

Source: *Efficiency Valuation Organisation*<sup>2</sup>

These principles guide all M&V decisions, but they apply for particular steps in the process more than others. The following section describes the six principles, and flags the sections of this document in which they become particularly important.

#### Accurate

M&V reports should be as accurate as possible within the budget of the project. Any accuracy tradeoffs should be conservative. This is particularly relevant to **5 Measurements**, **6.4 Statistical Tests**, and **7.8 Significant Figures**.

#### Complete

M&V should include all the effects of a project, measuring those that are significant and estimating others. This is particularly relevant to **4 Measurement Boundary** and **5 Measurements**.

#### Conservative

All estimates about uncertain quantities should understate savings. This is particularly relevant to **5 Measurements**.

<sup>1</sup> <https://www.veet.vic.gov.au/Public/Public.aspx?id=Project-basedactivities>

<sup>2</sup> <http://evo-world.org/en/m-v/principles-of-m-v>

## Consistent

The reported savings for a project should be consistent between different activities, time periods for measurements, and people working on the M&V. This is particularly relevant to [3 Baseline, Operating, and Reporting Periods](#), [4 Measurement Boundary](#), [5 Measurements](#), [7.2 Site Constants](#), [7.3 Eligible Time Intervals](#), and [7.7 Normal Year](#).

## Relevant

Only the relevant parameters (those that influence energy savings) should be measured. Particularly relevant to [4 Measurement Boundary](#), [5 Measurements](#), [7.2 Site Constants](#), and [7.5 Interactive Energy Savings](#).

## Transparent

M&V activities should be clearly and fully disclosed. This is particularly relevant to [4 Measurement Boundary](#), [5 Measurements](#), [7.2 Site Constants](#), and [7.5 Interactive Energy Savings](#).

### 1.4.1 Further Reading

#### External Resources

- *EVO IPMVP Core Concepts*, Section 4

## 1.5 M&V in Victorian Energy Upgrades

Apart from PBA, all methods for estimating energy savings in Victorian Energy Upgrades use what are known as deemed savings. Deemed savings are calculated from the average savings of installed equipment, and allow only for simple savings estimates of compliant equipment. These are essentially “off the shelf” energy efficiency activities.

In contrast, the PBA Regulations of Victorian Energy Upgrades provide for methods that calculate savings specific to a custom upgrades project. M&V is one such method. This method can help business invest in a much broader range of applications than methods of deemed savings. They also have the potential to create larger incentives.

However, this flexibility comes at a price. M&V is more complex and hence is likely to be costlier than a deemed approach, as each project requires a customised measurement and verification plan, and, once the project is implemented, determination of the actual savings. M&V is further limited by one’s ability to measure energy consumption prior to implementing the project. On the other hand, deemed savings are simple calculations based only on the installed equipment.

The Victorian Energy Upgrades M&V method differs in some ways from the IPMVP on which it was based. IPMVP is designed for the participants of energy efficiency projects to measure energy savings. It gives participants flexibility to choose an approach to suit their desired level of rigour and accuracy. In Victorian Energy Upgrades the Victorian Government also has a stake in the rigour and accuracy of M&V, because it is responsible for ensuring VEECs are created based on accurately determined energy savings. To manage this, the M&V method is more prescriptive than IPMVP. This is particularly the case with parameters such as site constants and effective range (see [7 Parameters](#)), and the M&V options allowed (see [1.7 M&V Options](#)).

Another difference to note is that the end point of M&V in Victorian Energy Upgrades is to calculate eligible greenhouse gas savings for the creation of VEECs. IPMVP M&V projects tend to focus on financial savings. The Victorian Energy Upgrades method does not calculate the bill saving estimates of projects; however, it does provide a rigorous basis from which bill savings can later be calculated.

## 1.6 Victorian Energy Upgrades M&V Calculation Options

Victorian Energy Upgrades offers three different M&V calculations to create VEECs:

- Calculating annual savings of a project using measured energy use to create certificates.
- Estimating future savings of a project to create certificates before the savings happen (‘forward creation’).
- Estimating future savings to forward create certificates, and then calculating annual savings to create new ‘top-up’ VEECs once the total actual savings exceed the original forecast.

These different calculations are detailed in [8 Equations](#).

### 1.6.1 Calculating Annual Savings

This calculation is used to create VEECs each year, based on the actual savings from the project over that year. This calculation method suits projects with large annual savings, or those in which it may be difficult to model future energy savings (for example, it may not be possible to define a normal year (see [7.7 Normal Year](#)) if operating conditions are expected to change significantly over time).

This calculation first requires measuring energy use and operating conditions before the project is installed (see [3.2 Baseline Period](#)). We then use statistical methods with these measurements to create a *baseline energy model* that explains how site energy use changes with different operating conditions (see [6.1 Baseline and Operating Models](#)).

After the project is implemented, the energy use and the operating conditions of the site are measured again for a reporting period (see [3.4 Reporting Period](#), [4 Measurement Boundary](#), and [5 Measurements](#)).

Then, we compare the reporting period measurements to the baseline energy model to determine how much energy would have been used if the project had never been implemented. The project savings are the difference between the actual measured energy use and the adjusted baseline energy use. This process is shown in Figure 3.

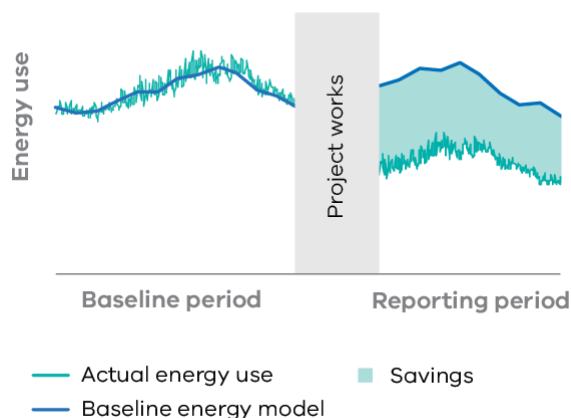


Figure 3: Using M&V to measure annual savings

### 1.6.2 Estimating Future Savings (Forward Creation)

This calculation allows VEECs to be created for future savings based on a measurement period after the project is installed. The benefit of using forward creation is that VEECs can be claimed earlier, which can make a project more financially attractive.

This calculation also requires measuring energy use and operating conditions before the project is implemented (see [3.2 Baseline Period](#)) to develop a baseline energy model. After implementation (see [3.3 Operating Period](#)), we measure energy use and operating conditions to develop an operating energy model (see [6.1 Baseline and Operating Models](#)).

We then define a normal year based on the expected operating conditions during the forward creation period, the future period over which we want to estimate savings (see [7.7 Normal Year](#)). We enter these expected conditions over the normal year into the operating energy model to estimate how much energy will be used over those future years.

We also enter the normal year conditions into the baseline model to estimate how much energy would have been used in the normal year if the project didn't go ahead. The annual savings for the project in the normal year is the difference between the operating energy use and baseline energy use. These savings are discounted over time to account for reduced savings from wear and tear on ageing equipment, using a decay factor (see [7.6 Decay Factor](#)).

Figure 4 depicts the normal year savings for a project.

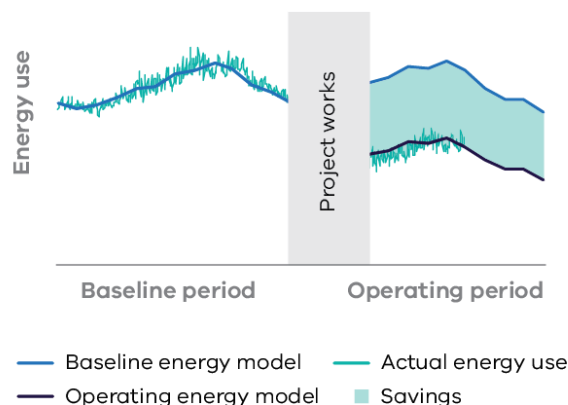


Figure 4: Using M&V to estimate savings in a normal year

This process is called forward creation. Forward creation can happen up to three times on a single project. Each use of the forward creation method will be based on a new operating energy model. These new models will be increasingly refined, as additional data is collected and the model describes the system more accurately. Multiple forward creations might be useful if the system wasn't working as well as expected during the initial operating period, or if project works are staged.

The total forward creation for an M&V project in Victorian Energy Upgrades is capped at 50,000 certificates over a maximum time period of ten years.



### 1.6.3 Forward Creation with Annual ‘Top-Up’ of Savings

This calculation combines forward creation and annual reporting. This will be relevant if, for example, the operating conditions have changed over time leading to much greater savings than estimated for a normal year. This calculation will also be used in projects with savings that exceed the 50,000 certificate cap on forward creation, as there is no limit on the number of certificates created through annual reporting.

As before, we measure energy use and operating conditions before the project is implemented to create a baseline energy model. After the project is installed, we measure energy use and operating conditions to create an operating energy model. Just as when estimating future savings, we apply the operating model to a normal year to estimate savings over a forward creation period. This forward estimate is then considered counted savings (see [8.6 Counted Savings](#)) as it has already been counted for the project.

During the life of the project, we measure actual energy use and operating conditions, and calculate project savings using the annual reporting calculation. Each year, we compare the cumulative measured savings to the counted savings. Once the cumulative savings exceed the counted savings, additional savings can be claimed in Victorian Energy Upgrades as a ‘top-up’. This process is explained in greater detail in Table 13 in [8.6 Counted Savings](#).

## 1.7 M&V Options

Not all M&V options are allowed under Victorian Energy Upgrades. Table 4 shows the four M&V options specified by IPMVP.

Table 4: IPMVP options in Victorian Energy Upgrades

IPMVP option	Description	Allowed in Program
A	Retrofit isolation: key parameters measured	✗
B	Retrofit isolation: all parameters measured	✓
C	Whole facility	✓
D	Calibrated simulation	✗

The options vary by coverage, methods of measurement, and the type of models used to calculate savings. These differences are explained in greater detail in sections [4 Measurement Boundary](#) and [5 Measurements](#).

### 1.7.1 Further Reading

#### Program Resources

- *VEET PBA Regulations*
- *DELWP M&V Methods and Variables*
- *ESC Activity Guidance, Section 4.2*

#### External Resources

- *EVO IPMVP Core Concepts, Section 6*

## 1.8 What Projects are Suitable for Victorian Energy Upgrades M&V?

The concept of M&V is broadly applicable to any project, but it may not always be appropriate. Whilst the benefits of energy efficiency projects can be considerable, M&V can be costly and complex to implement.

The IPMVP includes a range of methods suitable for any energy efficiency project. Option A is included in the IPMVP as a low cost means of estimating project savings with a lower level of certainty. As noted in Table 4 above, this option is not included in Victorian Energy Upgrades as the calculated savings are less certain than in other methods.

M&V in the Victorian Energy Upgrades entails measurement of energy use and relevant parameters before and after the project is implemented. It includes a detailed analysis of the project, including statistical modelling, to understand how the upgraded equipment uses energy and the physical factors that influence that energy use.

This is a relatively complex process that is customised to each project. M&V costs for Victorian Energy Upgrades projects will vary, but the complexity of the process means that costs will typically be several thousand dollars. Deemed methods, if available, will typically be a simpler and cheaper option to create VEECs for a project.

However, M&V is a very flexible approach, and it can be used to calculate savings from any project. The IPMVP Accuracy principle notes that “M&V costs should normally be small relative to the

monetary value of the savings being evaluated<sup>3</sup>. Given the range of M&V costs noted above, this

Project type	M&V suitable?
Large industrial efficiency projects	✓
Large HVAC upgrade	✓
Whole building retrofits	✓
Projects incorporating many savings initiatives that may interact	✓
Building envelope improvements	✓
Energy management systems (particularly alongside other savings initiatives)	✓
Simple equipment upgrades (motors, lighting, water heating, whitegoods)	Where deemed method is not applicable (e.g. operating conditions differ to deemed) or part of a larger upgrade

principle suggests that projects suited to M&V will generate savings worth tens of thousand of dollars. The cost of M&V for smaller projects is likely to be large relative to the savings.

For some projects, the cost of M&V may be spread over many sites. For example, a project may involve installing a particular piece of equipment or system upgrade that will deliver similar savings wherever it is installed. Once developed for one site, the same M&V approach could be repeated for each additional implementation of that project, which might reduce the M&V costs for new sites. However, multi-site projects are currently not allowed in Victorian Energy Upgrades, and each site will be treated as a separate M&V project.

The flexibility of M&V means it can be used to measure savings in a very broad range of projects. Using the Victorian Energy Upgrades M&V approach, you can calculate savings for projects involving:

- Very complex systems, such as integrated industrial processes, HVAC systems, and energy management systems

- Simultaneous upgrades at the same site, such as whole building upgrades or improvements to a manufacturing process
- Upgrades that affect energy use elsewhere on site (Refer to Section 4)
- Fuel switching and renewable energy projects

Table 5 outlines how some typical projects could participate in Victorian Energy Upgrades. Each of the projects is suited to M&V in Victorian Energy Upgrades as they will generate large savings, and are complex or customised upgrades that cannot be generalised using a simple deemed savings method.

**Table 5: Typical upgrade projects in Victorian Energy Upgrades**

Victorian Energy Upgrades also allows for projects to combine M&V with deemed methods to calculate savings most efficiently. When using more than one method at a site, be careful to avoid counting savings twice. Counted savings (such as certificates generated using a deemed method) must be excluded from the M&V savings calculations. It should be noted that M&V projects cannot be used to “top-up” incentives created by previous deemed methods.

Furthermore, the Victorian Energy Upgrades method allows for sampling to help reduce measurement costs. When a project involves many very similar components, the M&V plan can specify that only a suitable sample of these components be measured.

There are restrictions in the *VEET PBA Regulations* that limit it to certain projects. To use the M&V method, a project must:

- Be located at a business or non-residential premises, or in the common areas of a multi-unit residential building, or in buildings housing long-term or transient living spaces such as hotels, motels, and detention centres
- Not reduce greenhouse gas emissions by reducing production capacity or service levels, unless this is to correct over-servicing (such as excessive lighting or space heating)
- Be able to establish a baseline energy model. This means that M&V may not be possible if the project needs to be implemented in a short timeframe and historical data is not available

### 1.8.1 Further Reading

#### Program Resources

- *VEET PBA Regulations*, Regulation 6(8)

<sup>3</sup> EVO IPMVP Core Concepts, Section 4



- *DELWP M&V Methods and Variables*, Sections 4 and 14

#### **External Resources**

- *OEH M&V Guide: Applications* (detailed M&V guidance for different project types)

## 2 Energy Sources

The energy sources allowed in the *VEET PBA Regulations* include electricity, gas, and renewables. VEET certificates (VEECs) are generated based on the carbon dioxide equivalent of energy savings from the project.

### 2.1 Eligible Energy Sources

Projects using the M&V method must clearly specify the energy sources affected by the project.

An eligible project will reduce greenhouse gas emissions by saving either grid electricity or gas. It could also reduce emissions by switching from an energy source with a high emissions intensity (such as electricity) to one with a lower intensity (such as gas or a renewable energy source).

Projects that include energy generation are only eligible for M&V in Victorian Energy Upgrades if they do not export energy outside the measurement boundary (see [4 Measurement Boundary](#)).

#### 2.1.1 Further Reading

##### Program Resources

- *DELWP M&V Methods and Variables*, Section 7

### 2.2 Calculating Greenhouse Gas Savings

For any project, the overall greenhouse gas savings are calculated using Equation 1 from *DELWP M&V Methods and Variables*:

$$\begin{aligned} &\text{carbon dioxide equivalent} \\ &= \text{electricity savings} \times \text{electricity emissions factor} \times RF \\ &+ \text{gas savings} \times \text{gas emissions factor} \\ &+ \text{renewable energy savings} \times \text{renewable emissions factor} \\ &- \text{counted savings} \end{aligned}$$

Figure 5: M&V Equation 1

To determine the total savings for the project, you must first calculate the project savings for each energy source (electricity, gas, and renewable energy). A project that involves multiple energy sources will therefore also involve multiple energy savings calculations. Each calculation will require separate baseline and operating models, parameters, and equations (see [6 Energy Models](#), [7 Parameters](#), and [8 Equations](#)).

For some types of renewable energy sources, separate savings models are not required. Each energy source term in Equation 1 includes an emissions factor, defined for each energy source in *DELWP M&V Methods and Variables*, Section 9. Certain renewable energy sources have an emissions factor equal to zero, including solar, wind, hydroelectric, geothermal, and ocean energy. Since the emissions factors for these energy sources is zero, their greenhouse gas emission savings will also be zero, meaning separate savings models are not necessary. Figure 6 is an example of using M&V to create VEECs from a renewable energy project.

A dairy cold storage facility in Melbourne upgraded their building façade with Building Integrated Photovoltaics. The electricity generated by the system is entirely used on site.

VEECs will be created using the annual creation M&V method. The measurement boundary for the project is the whole site, to match the use of generated energy. To measure savings from the project, a baseline energy model is developed for the whole building using utility metered electricity data. There is no model for the electricity generated by the photovoltaic system, as it has an emissions factor of zero.

The measured savings are summarised below.

Year	Baseline	Measured	Savings
Year 1	6200 MWh	6000 MWh	200 MWh
Year 2	6300 MWh	6050 MWh	250 MWh

The emissions factor for electricity is 1.095, and the regional factor is 0.98. Using Equation 1, the site created  $(200 \times 1.095 \times 0.98) = 214$  VEECs in year 1. In year 2, the site created  $((250 + 200) \times 1.095 \times 0.98) - 214 = 268$  VEECs.

Figure 6: Creating VEECs for a renewable energy project

### 2.2.1 Further Reading

#### Program Resources

- *DELWP M&V Methods and Variables*, Section 9 and Equation 1
- Australian Government (2016) *National Greenhouse Accounts Factors 2016* Tables 1 & 3

## 2.3 Measuring Savings for Multiple Energy Sources

Calculating savings for multiple energy sources is more complicated, and more costly, than calculating savings for a single source. This is because measurements must be taken for each energy source. Each source will also require a unique baseline energy model, and, for forward creation, an operating energy model. This means that you will need to create a normal year for each energy source in the project when doing forward creation (see [3 Baseline, Operating, and Reporting Periods](#) and [6 Energy Models](#)).

Aligning measurement periods and independent variables will help to reduce the cost and effort of creating these additional models.

Aligning the different measurement periods may be challenging for energy sources with irregular delivery schedules (such as deliveries of bottled gas). Whenever possible, it's best to submeter the use of each energy source instead of using inventory readings or delivery information. Submetered data is more easily aligned with other data, and will generally result in better energy models.

To reduce measurement costs, projects with multiple fuels should ideally choose similar independent variables. However, the factors that drive energy use may differ greatly between different fuels, so additional independent variables may be unavoidable in some cases.

### 2.3.1 Further Reading

#### External Resources

- *DoE FEMP Guidelines*, Section 4.4.2
- *EVO IPMVP Core Concepts*, Section 6.5.3

## 2.4 Energy sources in the Victorian Energy Upgrades M&V Workbook

The *Victorian Energy Upgrades M&V Workbook* will calculate savings for projects with up to three energy sources, including electricity, gas, and renewable energy. Select the relevant energy sources for the project from the drop-down list on the Project

Summary tab of the workbook. As an energy source is added to the project, the *Workbook* will automatically add the worksheets and calculations needed to create models and calculate savings for each energy source.

After you have completed the M&V models and calculations for each energy source, the workbook applies appropriate emissions factor for the selected fuels to calculate the overall greenhouse gas savings for the project in the GHG savings tab.

## 3 Baseline, Operating, and Reporting Periods

M&V savings require a clear understanding of the energy use before project implementation. Under Victorian Energy Upgrades, savings that are forward created are based on the energy use during an operating period after the project is implemented. Savings that are reported annually are based on energy use during reporting periods.

### 3.1 Measurement Periods in Victorian Energy Upgrades

M&V estimates project savings by comparing the energy use after the project was implemented with the energy that would have been used had the project not been implemented.

In Victorian Energy Upgrades, energy use is first measured during a baseline period before the project begins. Savings are then calculated using measurements taken during an operating period (for forward creation of certificates), during a reporting period (for annual reporting of savings), or during both an operating and reporting period (for forward creation with an annual top-up).

Table 6: Measurement periods for different project types

Project type	Baseline period	Operating period	Reporting period
Annual reporting	✓	✗	✓
Forward creation	✓	✓	✗
Forward creation with top-up	✓	✓	✓

Table 6 shows measurement periods for different types of Victorian Energy Upgrades M&V projects. Figure 7 depicts measurement periods in a Victorian Energy Upgrades M&V project.

#### 3.1.1 Measurement Periods for Multiple Fuel Projects

When undertaking M&V on projects that involve multiple fuel sources, separate energy models will be required for each fuel. Aligning measurement periods and independent variables will help to reduce the cost and complexity of the project M&V (see [2.3 Measuring Savings for Multiple Energy Sources](#)). Aligning the measurement periods for each fuel also helps to ensure that the reported savings are consistent (see [1.4 IPMVP Principles](#)).

### 3.2 Baseline Period

The baseline period covers a period of time before the project is implemented, and may range from less than one week to more than one year in length. The exact length of the baseline period is chosen based on site operating conditions. The baseline period must end within 24 months of the beginning of the project.

Choosing the right baseline period is important, as measurements taken during this period must accurately represent how energy is used before the project is implemented. These measurements will allow you to develop a baseline energy model. There are several considerations when establishing a baseline period, including the operating cycle of the equipment, metering and data availability, and whether the effects of the project can be temporarily disabled.

#### 3.2.1 Operating cycle

The baseline model should include the full range of variations in operating conditions, which means that the baseline period should cover at least one full operating cycle of the equipment affected by the project.

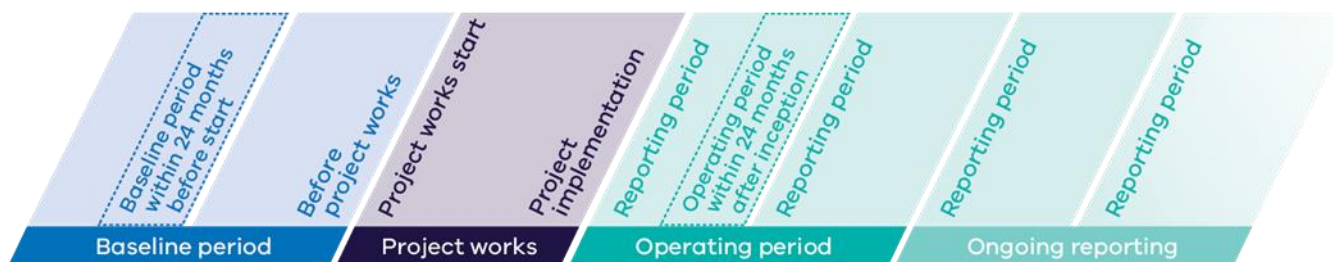


Figure 7: M&V timeline

If the baseline period does not include the full range of operating conditions, the savings calculations may have a high degree of uncertainty, which would result in fewer VEECs. However, this approach might be best if it is balanced by lower costs.

For projects in which seasonality is a factor, the full operating cycle could be as long as one year. For example, the energy used in a Heating, Ventilation, and Air Conditioning (HVAC) system depends on weather conditions that vary during the year.

In other cases, the operating cycle may be reasonably short. For example, an upgrade of lighting controls and equipment may require between one week and one month of data.

The *OEH M&V Guide: Applications* offers suggested measurement periods for different M&V project applications, shown in Table 7.

**Table 7: Suggested baseline periods for different M&V projects**

M&V method	Suggested baseline period
Retrofit isolation	Between one week and one month. Repeat periodically if seasonality is an issue (e.g. school terms for lighting, winter/summer for HVAC)
Whole site or metered sub-site	At least one site operation cycle that includes changes to other energy systems. For example, 12 months is required where seasonality is a factor

### 3.2.2 Data Availability


The choice of baseline period can significantly affect project timelines, as you will need measurements during the entire baseline period. If data is not already available (for example, from utility meters or existing site submeters) the need to gather new data may impact the timeframe for project implementation.

Alternative M&V strategies (such as different measurement boundaries) can help to avoid or reduce these delays. For example, utility information is likely available for longer baseline periods. A whole-site or metered sub-site approach may mean that energy and site information is already available for the baseline period. However, choosing this sort of approach may not always be viable, particularly if the expected energy savings from the project will only be a small amount of the total metered energy use of the site (see [4 Measurement Boundary](#) for more information).

### 3.2.3 Suspending the Effects of the Project

In limited circumstances, *DELWP M&V Methods and Variables* allows for a baseline period to end after work on the project has begun. This option is permitted when the effects of the project can be suspended such that the measured energy use and other relevant variables would be the same as if the project had not yet begun (for example, consider a controls system upgrade that can be temporarily switched back to pre-upgrade settings). On the other hand, if the project involves removing and replacing existing equipment, it will generally not be possible to suspend the impact of the project, so this option is unavailable.

If it is available, this option can help avoid delays due to baseline measurements. It may also be useful if a parameter that is otherwise constant is expected to change as part of the project (such as increased operating hours – see [7.2 Site Constants](#)).

 It is recommended that this option is explored with the ESC before a decision is made.

### 3.2.4 Further Reading

#### Program Resources

- *DELWP M&V Methods and Variables*, Sections 12(b) and (c)
- *ESC Activity Guidance*, Section 4.4.1 and 4.3

### 3.3 Operating Period

When forward creating savings for a project, you will need to include an operating period that takes place within two years of the implementation of the project (referred to as inception in Figure 7). The operating period is used to establish an operating energy model for the project, which shows how much energy is used after the project is implemented (see [6.1 Baseline and Operating Models](#)). By comparing the baseline and operating energy models, energy savings for the project can be estimated up to ten years in the future.

The *VEET PBA Regulations* allows for up to three forward creation calculations for the same project, as described in Section 1.6. These calculations will reflect the difference between the operating energy model and baseline energy model, projected forward for up to ten years. Each forward creation will relate to a different operating energy model based on a different operating period. The operating period for a subsequent forward creation should include and extend the operating period for an earlier forward



creation, using the additional data to refine the operating energy model.

The purpose of forward creation is to estimate future energy savings from the project. Multiple forward creation calculations may be desirable for cases where information about the project savings improves over time. An example of multiple forward creation is given in Figure 8 below.

A food manufacturer installs a co-generation system in July 2018. The operating period for the project is set as July 2018 to June 2019. Certificates are forward created for ten years based on savings calculations in this operating period. However, the first six months of this period were affected by commissioning issues, reducing savings.

A second operating period from February 2019 to January 2020 showed significantly greater operating savings, as the system was fully commissioned and operating efficiently. A second forward creation for the site created additional certificates based on the higher savings.

**Figure 8: Example of multiple operating periods**

### 3.3.1 External Resources

- *DELWP M&V Methods and Variables*, Section 12(d)

## 3.4 Reporting Period

The first reporting period is the twelve-month period that begins immediately after a project is implemented. A second reporting period of twelve months begins immediately following the first reporting period, a third can begin after that, and so on. A project can have up to ten reporting periods. VEECs can be annually created after each reporting period.

Reporting periods are used when creating certificates based on annual measured consumption data. The energy and operating conditions will be measured throughout the year.

Reporting periods are also used for 'top-up' creation of certificates after forward creation, if the cumulative annual savings for the project exceeds the certificates that were forward created.

Projects using annual or top-up creation need to account for savings for each year since the project was implemented.

### 3.4.1 Resources

- *DELWP M&V Methods and Variables*, Section 10

## 3.5 Baseline, Operating and Reporting Periods in the Victorian Energy Upgrades M&V Workbook

The baseline, operating and reporting periods for a project are outlined on the Measurements tab of the *Victorian Energy Upgrades M&V Workbook*. On this tab, you will define the measurement frequency for the energy models, independent variables and site constants, and the measurement strategy and accuracy of each measurement.

Once the Measurements tab is completed, the workbook will generate worksheets for you to record all the relevant measurements for the project for each time interval.

The measurements for baseline period of the project are entered in the Baseline Measurements tab. For each time interval, the workbook includes a space to enter the measured energy use, independent variables and site constants. You can also mark time intervals for exclusion from calculations when required along with a note explaining the exclusion.

For a forward projection, measured operating period data is similarly entered in the Operating Measurements tab in the workbook.

For annual reporting, measured reporting period data is entered in the Reporting Period Values tab of the workbook.

## 4 Measurement Boundary

The measurement boundary is a consistent reference point to measure energy consumption before and after the project is implemented. This shapes other important M&V decisions and is one of the most critical choices made at planning stage.

### 4.1 Choosing a Measurement Boundary

Choosing an appropriate measurement boundary for the project is an important step in measuring the reduction of greenhouse gas emissions. The measurement boundary is drawn around energy-generating and -consuming equipment affected by the project. To establish project savings, the energy consumption and generation of all equipment within the boundary will be measured.

There are two primary options when selecting an appropriate boundary under Victorian Energy Upgrades:

- Measuring the energy use of the whole site or metered sub-site using utility meters (option C under IPMVP)
- Measuring only the energy use of equipment<sup>4</sup> that is directly affected by the project (a “retrofit-isolation”) using sub-meters (option B under IPMVP)

In both cases, the measurement boundary must include all the energy-generating and -consuming equipment installed or removed for the project, and any other energy-generating and -consuming equipment that will change due to the project. Energy generators may not export energy outside the measurement boundary.

Any energy changes that take place outside the measurement boundary will be considered interactive energy savings (see [7.5 Interactive Energy Savings](#)). If the changes are trivial and would be impractical or disproportionately costly to measure, they may be documented and ignored in savings calculations. If interactive energy savings

are moderate, they may be estimated using methods that do not involve long term measurement. If the interactive energy savings are expected to be large, the measurement boundary should be redrawn to include the impacted system. You need to justify the treatment of interactive energy savings. For example, whether they are noted, estimated or measured.

#### 4.1.1 Further Reading

##### Program Resources

- *DELWP M&V Methods and Variables*, sections 7 and 16
- *ESC Activity Guidance*, Section 4.5

##### External Resources

- *EVO IPMVP Core Concepts* October 2016, section 6
- *OEH M&V Guide: Best Practice Processes*, section 4.1.2 and 4.1.4

### 4.2 Key Considerations

Key considerations for choosing the measurement boundary include:

- Size of the expected savings relative to total energy consumption
- Cost of collecting retrofit isolation data
- Expected changes that may affect savings
- Existing metering arrangements and data availability (both historical and future)
- Minimising interactive energy savings
- Inclusion of energy generation projects

Table 8 summarises the key considerations when selecting a measurement boundary type. The following sections detail these considerations.

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<sup>4</sup> Victorian Energy Upgrades refers to equipment as “energy saving products”.



**Table 8: Guide to selecting a measurement boundary**

Project characteristic	Isolation	Whole site
Expected savings are less than 10% of utility meter	✓	
Interactive effects can be reasonably estimated or are insignificant	✓	
Possible changes to the site may be difficult to establish or assess	✓	
Significant interactive effects		✓
Energy use varies over time, and no existing isolation data is available		✓
Energy use does not vary over time	✓	
Project includes energy generation		✓

#### 4.2.1 Size of the Expected Savings Relative to Total Energy Consumption

The choice of measurement boundary can affect the quality of the energy model, which in turn affects VEEC creation.

A whole-site measurement boundary is likely to include a broad range of energy-consuming equipment of varying sizes and with energy consumption that changes based on different factors. Creating energy models that explain these different factors at the whole-site level can be challenging. The more complicated the site, the less likely a model will be able to explain the variations in energy use.

The complexity of a whole-site model may be reduced by using a sub-site approach. This involves choosing the measurement boundary based on an energy meter that measures energy consumption for a part of the site that includes all the equipment affected by the project. For example, this could mean upgrading a process line in a textile factory, where the line has a sub-meter installed.

The IPMVP recommends that, as a rule of thumb, whole-site (or sub-site) measurement boundaries should only be used if the expected savings are greater than 10% of metered consumption. Energy savings lower than this may be difficult to distinguish from unexplained variations in energy use. However, this rule of thumb depends upon the how well the energy model can predict the variability of the

baseline data. If the energy use under typical conditions is very predictable, even low (less than 10%) energy savings may be predicted with certainty, allowing us to use M&V to calculate energy savings for the project and create VEECs.

#### 4.2.2 Expected Changes to the Site

The measurement boundary can also affect the number of eligible time intervals. Only eligible time intervals can be used to calculate the savings and create VEECs.

Using a whole-site measurement boundary also means that any changes to the site during the reporting period will need to be monitored. This includes changes that do not directly affect the equipment involved in the project. For example, parts of the site that are not serviced by the project may be shut down during the period, production levels on a different production line may change, or additional services may be added to another part of the site.

When many changes to the site are expected, or it will be hard to assess future changes, it may be preferable to use a retrofit-isolation measurement boundary rather than a whole-site boundary. This is particularly important if the site changes are expected to have a significant impact on energy use, and cannot be replicated during the baseline period. Factors that have a significant impact on energy consumption, but are not expected to change during the baseline period, will be noted as site constants. If these site constants change during the operating or reporting period, the model may become invalid, which will prevent savings from being credited during those times (see [7.2 Site Constants](#)).

#### 4.2.3 Existing Metering Arrangements and Data Availability

The availability of data for the different measurement boundary options may have a significant effect on lead-in times for the project.

In order to measure project savings, before the project is implemented we must measure energy data and operating conditions for equipment within the measurement boundary. This data will be used to develop the baseline energy model. This model will only be valid for calculating energy savings when the operating conditions are within the 'effective range' ( $\pm 5\%$ ) of the model (see [7.4 Effective Range](#)). If the effective range is much smaller than future operating conditions, you will not be able to claim all the project savings.

For example, if the project affects equipment with energy use that normally varies based on climate (such as air conditioning), the baseline energy model should include energy consumption data for that equipment that covers the full range of climate conditions. If data for summer or winter is not available, this may mean that savings during these seasons cannot be calculated, as they are outside the range of the model.

The availability of data reflecting the likely range of operating conditions will affect the measurement boundary for the project. If the affected equipment is already sub-metered, and data reflecting the likely range of operating conditions is available, a 'retrofit-isolation' approach may be appropriate. However, if new sub-meters must be installed to isolate and measure the energy use of any equipment, the project cannot be implemented until enough data has been gathered to build a valid energy model. When energy use varies over time, a whole-site approach is likely to be preferable to avoid extensive implementation delays, because historical utility metering is already available.

#### 4.2.4 Minimising Interactive Energy Savings

In general, interactive energy savings should be kept to a minimum, and must be less than 10% of the calculated energy savings. For projects with energy savings that are not significant at a whole-site level, but with potentially significant interactive energy savings, it may be preferable to isolate the energy equipment that is affected by the upgrade and

include it in an expanded measurement boundary.

#### 4.2.5 Inclusion of Energy Generation Projects

*DELWP M&V Methods and Variables* states that energy-generating equipment in Victorian Energy Upgrades cannot export energy outside the measurement boundary of the project. This means that projects including energy generation will need to include both the energy generator and any energy consuming equipment attached to it. For electricity generation, this may mean that the measurement boundary is the whole site. Figure 6 in section 2.3 gives an example of creating VEECs from a renewable energy project.

#### 4.2.6 Further Reading

##### Program Resources

- *DELWP M&V Methods and Variables*, Section 7
- *ESC Activity Guidance*, Section 4

##### External Resources

- *EVO IPMVP Core Concepts* (October 2016), Section 6
- *DoE FEMP Guidelines* (Version 4.0), Section 4
- *IPART PIAM&V Method Guide*, Sections 3.7 and D.3.1
- *OEHL M&V Guide: Best Practice Processes*, Section 4.1.2

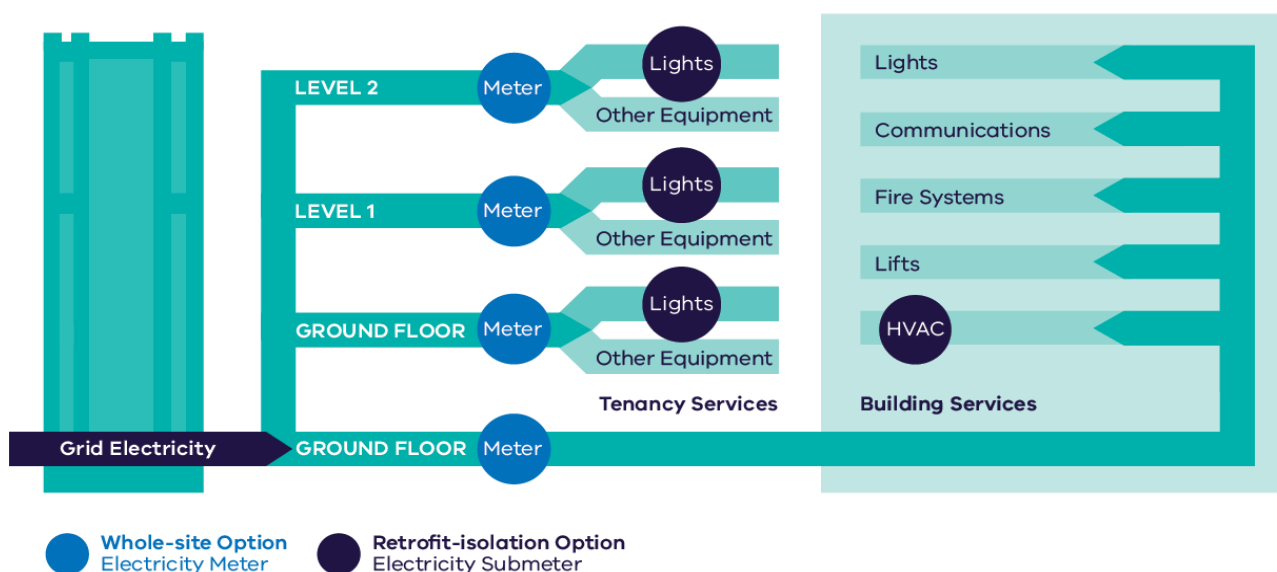


Figure 9: Example measurement boundary

### 4.3 Example

Figure 9 outlines a typical small commercial building metering arrangement, with utility electricity meters for each floor of the building and a separate utility meter for base building services.

A whole-site measurement boundary for this building would include one or more of the light blue utility electricity meters.

A retrofit-isolation boundary for this site would depend upon the extent of the project. In this example, the project upgrades equipment in each of the areas downstream of the light blue utility electricity meters, including base building HVAC and new lighting on each floor of the building. A retrofit-isolation boundary for this project would require measuring the energy consumption of all this equipment using several sub-meters, shown in dark blue.

### 4.4 Measurement Boundary in the *Victorian Energy Upgrades M&V Workbook*

The measurement boundary for the site is described along with the overall project description in step 1 of the Measurements & Variables tab in the *Victorian Energy Upgrades M&V Workbook*. The workbook includes space for a description of the measurement boundary.

## 5 Measurements

M&V requires measurements of energy use and other variables before and after the energy savings project is implemented. You should balance the accuracy of energy savings estimates with measurement cost to minimise overall M&V costs.

### 5.1 What to Measure

Measurements of energy consumption within the measurement boundary and independent variables will need to be obtained during the baseline period (for all projects) and operating period (for projects using forward creation). Projects using annual creation will need to measure energy consumption for each reporting period, and projects using top-up will need to account for reporting and operating periods.

*DELWP M&V Methods and Variables* specifies that, when creating energy models, one must include measurements from at least 80% of the time intervals within the relevant period.

Apart from this, there are very few regulatory requirements for M&V measurements in Victorian Energy Upgrades. For example, measurement types and measurement accuracy are not regulated. However, these factors should be considered, as they may affect savings calculations.

The following sections describe factors to consider when creating the M&V measurement strategy for a project.

#### 5.1.1 Further Reading

##### External Resources

- *EVO IPMVP Core Concepts*, 6.5.6

### 5.2 Duration and Frequency

Measurement duration will match the baseline, operating, and reporting periods (see [3 Baseline, Operating, and Reporting Periods](#)) for the project. As noted in that section, the durations of the baseline and operating periods are based on the operating cycle of the equipment affected by the project (a reporting period is always 12 months long).

For example, if the project's energy use changes depending on the weather, you may need to collect at least eight months and perhaps a full year of data to cover the full range of seasonal temperatures.

Another example is if the project's energy use is affected by occupancy rates. In this case, the duration of data collection must be long enough to capture routine variation, and may need to include factors such as weekend and holiday occupancy, to maximise the effective range of the calculation and capture more savings. Evidence could be captured and recorded to justify the length of routine variation – for example, swipe access details which provide information on seasonal building use.

To determine measurement frequency, your goal is to obtain sufficient data to build a representative and accurate model. High frequency measurements, such as hourly meter readings, result in high variation of data. To develop an accurate model from this highly variable data, you may need to include high frequency explanatory variables in your model. In contrast, low frequency measurements result in less variation of data, but offer a much smaller dataset with which to build a model.

For energy models based on regression analysis (see [6.2 Regression Analysis](#)), each independent variable must be measured at least as often as six times the number of variables. This means that at least six measurements will be needed with one independent variable, twelve measurements of both independent variables if there are two, and so on. This will be a key consideration for projects with monthly energy billing cycles.

Energy data will often be available at a higher frequency than measurement data of independent variables. In these cases, it may be useful to aggregate your energy data to create lower frequency measurements that match the other measured data.

Using variable measurement intervals (such as months, which vary in length) can make it difficult to develop an accurate model. For example, gas energy measurements for small users may be based on infrequent meter readings, with varying meter data that may not be clear on bills.

*DELWP M&V Methods and Variables* requires time intervals to be of equal length for measurements of an energy source. This can create challenges for energy sources billed at infrequent or irregular intervals. In some cases, additional monitoring of the energy source may be required to obtain proper measurements.

### 5.2.1 Further Reading

#### Program Resources

- *DELWP M&V Methods and Variables*, Sections 12 and 19

## 5.3 Accuracy and Precision

Energy models for M&V are built using statistical techniques (see [6 Energy Models](#)).

The relative precision (see [6.4 Statistical Tests](#)) of the model describes how well it explains the observed variation in energy use. It should consider uncertainty from the model, measurement equipment and any sampling.

The model does not need to explain all variation to estimate energy savings. The relative precision of a model can be improved by reducing errors caused by M&V assumptions, statistical analysis, and the quality of measurement equipment. For example, models built on measurements with a high degree of error will have a poor relative precision.

You can avoid this problem by using accurate measurement equipment during the baseline, operating, and reporting periods. *EVO IPMVP Core Concepts* (section 6.2.2) recommends that the M&V plan “follow good measurement practices to enable calculation of energy savings with reasonable accuracy and repeatability.” Table 9 summarises IPMVP recommendations for typical measurement issues. For other sources, such as gas or steam, consider using existing metering arrangements with known accuracy, and utility grade submeters where possible.

**Table 9: Measurement equipment recommendations**

Measurement issue	IPMVP recommendation
Choosing equipment to measure electricity	Instrument that measures voltage, amperage, and power factor, or true Root Mean Squared wattage
Calibrating equipment to measure electricity	Calibrated as recommended by the manufacturer and following procedures of recognised measurement authorities
Documentation	Document specifications including accuracy and precision for non-utility meters

Source: *EVO IPMVP Core Concepts*, Sections 6.2 and 7.1

Based on the relative precision of your energy model, an accuracy factor is applied to the calculated energy savings. The accuracy factor

directly discounts savings, so you should aim to optimise model precision. However, keep in mind that that precision improvements will usually increase M&V costs.

Table 1 in *DELWP M&V Methods and Variables* lists the accuracy factor given the relative precision of an energy model. The higher the accuracy factor, the more certificates can be claimed. The highest possible accuracy factor is applied to models with a relative precision less than 25%, so there is little benefit in seeking extra precision after this point.

### 5.3.1 Further Reading

#### Program Resources

- *DELWP M&V Methods and Variables*, Table 1
- *ESC Activity Guidance*, Section 4.12

#### External Resources

- *EVO IPMVP Core Concepts*, Sections 6.2 and 7.1
- Efficiency Valuation Organisation (2014) *Statistics and Uncertainty for IPMVP*, Sections 1 and 4

## 5.4 Calculated Data

Very often the data used in M&V calculations will be derived from direct measurements. This may involve calculating data based on measurements (for example, converting daily temperature readings into cooling degree days), or combining high frequency measurements to match lower frequency time intervals.

For example, a typical independent variable such as cooling degree days will be calculated on a daily basis. The measured data for a cooling degree day is the maximum and minimum temperature of the day. Deriving a cooling degree day from this data is a simple calculation (detailed in section 7.7.1). Another simple independent variable may be the operating conditions of a commercial building, based on whether the day is a normal working day or a weekend/holiday. In this case, the independent variable will be derived from publicly available information.

The frequency of energy meter measurements will usually be much higher than the independent variables in the model. Electricity data is often metered on a 15-minute basis or even more frequently, while independent variables will often be hourly or daily.

In this case, the energy data used in calculations will be a sum of all the meter readings within each time interval. Ensuring consistent time intervals for



measured data, often achieved by deriving data from high frequency measurements, is an important part of the M&V process for a project.

## 5.5 Sampling

If a project involves multiple similar components at the same site, you can reduce M&V costs by measuring only a sample of these components. This could apply to projects such as lighting retrofits or other equipment changes involving many units of the same type of equipment.

The sampling approach is only allowed if any one of the sampled items could be expected to use the same amount of energy as any of the others in the project, under certain operating conditions. For example, in a lighting project with occupancy sensors, lights in a room occupied continuously (such as an open office space) would not be expected to use the same amount of energy as lights in a room not occupied continuously (such as a meeting room). Therefore, these systems would need to be grouped and sampled separately.

An appropriate measurement sample must also be selected at random. Random selection could mean drawing lots or using random number generators to determine a sampling order.

The accuracy of your energy model will be affected by the accuracy of your sample. If you're confident that the sample accurately represents the total population, its impact on model accuracy will be low. However, if you're not confident that the sample accurately represents the population, it will have a negative impact on model accuracy. See the Efficiency Valuation Organisation's *Statistics and Uncertainty for IPMVP* as a helpful guide when estimating sampling error.

### 5.5.1 Further Reading

#### Program Resources

- *DELWP M&V Methods and Variables*, Table 1
- *ESC Activity Guidance*, Section 4.12

#### External Resources

- Efficiency Valuation Organisation (2014) *Statistics and Uncertainty for IPMVP*, Section 3

## 5.6 Measurements in the Victorian Energy Upgrades M&V Workbook

The plan for measuring energy, independent variables, and site constants is documented on the Measurements tab of the *Victorian Energy Upgrades*

*M&V Workbook*. Enter the measurement strategy for each measurement including measurement frequency, and the accuracy of the measurement. You should also detail the strategy for transforming any measured data for energy models – for example, aggregating high frequency meter readings for lower frequency time intervals.

Use the “add row” button as necessary for M&V projects with independent variables and site constants.

The workbook will automatically generate templates for the project for the entry of measured data for the baseline, operating and reporting periods (as relevant to the project). The template will be customised to the measurement strategy of the project, with space for each measurement needed to complete the calculations.

Note that The *Victorian Energy Upgrades M&V Workbook* automatically calculates the relative precision for M&V models in Part 6 Statistical Analysis of both the Baseline Model and Operating Model tabs.

## 6 Energy Models

Energy models are the basis of savings calculations in the *VEET PBA Regulations*. Energy models are a statistical description of the system being measured. Models predict energy consumption using either an estimate of the mean, or a regression analysis based on explanatory variables that can be measured or otherwise determined.

### 6.1 Baseline and Operating Models

For M&V in Victorian Energy Upgrades, measurements of energy use and operating conditions must be taken both before and after the project is implemented. Using statistical techniques on these data, we can build energy models that describe how energy use changes with changing operating conditions. We can then use this information to estimate how much energy would have been used without the energy savings project.

There are two types of energy models in Victorian Energy Upgrades: the baseline energy model (created using measurements from the baseline period) and the operating energy model (created using measurements from the operating period). To create these models, there are two statistical techniques you can use: regression analysis and an estimate of the mean.

### 6.2 Regression Analysis

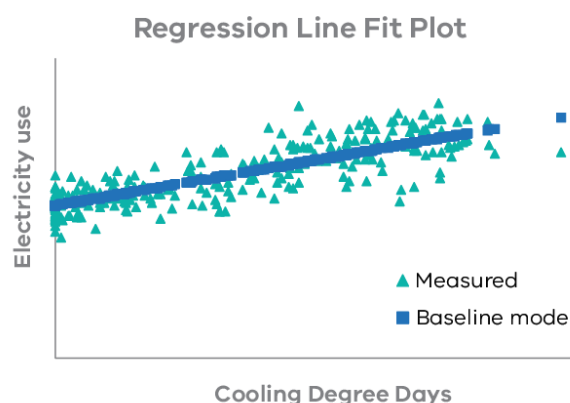
A regression analysis is a statistical model that describes the relationship between a dependent variable and one or more independent variables. In M&V for Victorian Energy Upgrades, the dependent variable is energy use. The independent variables are operating conditions that influence energy use and that change during the baseline, operating, and reporting periods. Common independent variables include site production levels, weather conditions (particularly for HVAC projects), occupancy levels, and the like. Regressions are usually a linear relationship between the dependent and independent variables. A linear regression model will be expressed in the following form:

$$Y = a + b_1X_1 + b_2X_2 + \dots + b_nX_n + \varepsilon$$

Where

- $Y$  is the dependent variable (energy use)
- $a$  is a constant and depends on site factors that increase energy use, but do not vary during the measurement period
- $X_i$  is the  $i^{\text{th}}$  independent variable that influences energy use
- $b_i$  is the coefficient for the  $i^{\text{th}}$  independent variable, determined by the regression analysis
- $\varepsilon$  is the residual error that is not explained by the model (the regression analysis aims to minimize the total error)

The regression model describes the expected value of the dependent variable for any given observation of the independent variables, as shown in Figure 10.



**Figure 10: Linear regression with one independent variable**

Regression models are particularly suited to M&V projects like weather-dependent energy systems, improved production processes, and other upgrades with known and measurable factors that influence energy use.

Key decisions when building a regression model include:

- *Choosing the right independent variables* – Are they truly independent? Can they be determined and measured? How do we expect them to influence energy use, and do the statistics align with this expectation?
- *Choosing appropriate time intervals* – Are some measurements taken much more frequently than others? Can you measure the independent variables as frequently as the dependent variable? Will you have enough data points to build a sufficiently precise model?



- *Ensuring the model has a sufficient effective range* – Does the range of independent variables in the baseline model match the expected range across the reporting period or normal year?
  - > For example, are the production levels measured in a manufacturing plant during a few months representative of the plant's yearly production cycle?
- *Ensuring that the model is statistically valid* – Are the t-statistic, adjusted  $R^2$ , and relative precision within acceptable limits?
  - > For example, does the baseline model correlating food weight and energy use in a large freezer room have a valid adjusted  $R^2$ ?

See section [7 Parameters](#) for guidance on these and other decisions when building an energy model.

### 6.2.1 Further Reading

#### Program Resources

- *ESC Activity Guidance, Section 4.4*

#### External Resources

- Efficiency Valuation Organisation (2014) *Statistics and Uncertainty for IPMVP*, Section 2
- *IPART PIAM&V Method Guide*, Section D3.3
- Australian Government (2013) *Energy Efficiency Opportunities Energy Savings Measurement Guide* (particularly the example in Sections 1.4 and 1.7)

## 6.3 Estimate of the Mean

In some cases, a regression analysis will not be possible. For example, there may not be any independent variables that influence energy consumption. Or, energy consumption may vary by such a small amount that no relationship can be shown between the proposed independent variables and the energy consumption.

In these cases, an estimate of the mean is a useful alternative approach. An estimate of the mean is a relatively simple calculation based on average energy consumption over the measurement period, and will be expressed in the form.

$$Y = \bar{X}$$

Where

- $Y$  is the dependent variable (energy use)
- $\bar{X}$  is the arithmetic mean of energy measurements over the measurement period

An estimate of the mean approach can only be taken when the measured energy data is relatively steady—*DELWP M&V Methods and Variables* requires that the coefficient of variation of the measured data be less than 15%. The coefficient of variation is calculated by the following formula:

$$CV = \left( \frac{SD}{\bar{X}} \right) \cdot 100$$

Where

- $CV$  is the coefficient of variation for the measured data
- $SD$  is the standard deviation of the measured data
- $\bar{X}$  is the mean of the measured data

If the measured energy consumption data for your project does not vary significantly, the estimate of the mean can be an easy and low cost approach to M&V. Projects that may be suited to this approach include projects in sites with continuous operation under a fixed load – for example, the drive of a pump operating continuously at a fixed flowrate, which is replaced by a higher efficiency model.

In some cases, it will be possible to use either regression or an estimate of the mean to build an acceptable energy model. Regression models are likely to be of higher quality, and therefore the M&V method rewards them with higher accuracy factors (see section [5.3 Accuracy and Precision](#)).

Figure 11 gives an example of energy measurement data that may be suitable for an estimate of the mean approach.

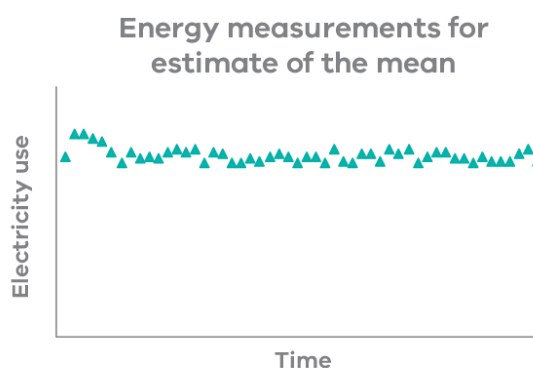


Figure 11: Energy measurements that may be suitable for an estimate of the mean model. Note the low variation of the data.

### 6.3.1 Further Reading

#### Program Resources

- *ESC Activity Guidance, Section 4.4*

## External Resources

- *IPART PIAM&V Method Guide*, Section D3.3

## 6.4 Statistical Tests

Statistical tests are used to determine the effectiveness of a model. A range of statistical tests should be performed on the energy models used in M&V, both to demonstrate their effectiveness and determine their relative precision.

For an estimate of the mean, the only statistical test needed to check the effectiveness of the model is the coefficient of variation, as described in section [6.3 Estimate of the Mean](#).

The most common statistical tests for a regression analysis are:

- The t-statistic of independent variables
- The adjusted  $R^2$  of the model
- The relative precision of the model
- Residuals check

Guidance for the results of each common statistical test is shown in Table 10.

**The t-statistic:** The t-statistic of an independent variable is a test of its impact on the model. A large t-statistic indicates that the independent variable has a large impact, while a small value indicates a small impact. Independent variables with a low t-statistic should be excluded from the analysis, as they don't help to explain variation in energy use.

**Adjusted  $R^2$ :** The adjusted  $R^2$  test reveals how well the model fits the measured data. An adjusted  $R^2$  value of 1 indicates that the model fits the data perfectly. The adjusted  $R^2$  of a model will decrease if the model does not fit the data well.

The adjusted  $R^2$  test can help identify and avoid over-fitting. An over-fit model is one in which the model is too complex for the data. This can happen if there are too many independent variables added, or a complicated non-linear model is used to describe variations in a simple dataset.

Over-fit models are misleading, since they're tailored to the original set of measurements and so appear to match the data. However, including additional data is likely to change the model. A rule of thumb to avoid over-fitting is to ensure that there are at least 10 to 15 measurements for every variable in the

model (including the dependent variable)<sup>5</sup>. Under the Victorian Energy Upgrades rules, the model is only considered valid if there are at least six times as many sets of measurements as independent variables.

**Relative precision:** The relative precision of a model describes the relative range of measured values of the dependent variable for a given confidence level. The relative precision of the model is affected by measurement error (see [5.3 Accuracy and Precision](#) and [5.4 Calculated Data](#)) and how well the model fits the data. The relative precision determines the accuracy factor for the calculations, and thus directly affects the number of certificates that can be claimed.

**Residuals check:** In a regression analysis, residuals refer to the difference between measured and predicted values of the dependent variable. In an effective linear regression analysis, these residuals should be random. Non-random residuals could indicate that a different model may fit the data better, or that there are missing explanatory independent variables.

A residuals check involves making a residuals plot and visually checking that it appears to be random. The example in Figure 11 shows a randomly distributed residuals plot. See Origin Help<sup>6</sup> or the Engineering Statistics Handbook<sup>7</sup> for more information on checking residuals.



Figure 12: Randomly distributed residuals plot

<sup>5</sup> Frost, J (2015). "The Danger of Overfitting Regression Models", *Minitab Blog* <http://blog.minitab.com/blog/adventures-in-statistics-2/the-danger-of-overfitting-regression-models>

<sup>6</sup> Origin Lab. "Regression and Curve Fitting - Residual Plot Analysis", *Origin Help*, [originlab.com/doc/Origin-Help/Residual-Plot-Analysis](http://originlab.com/doc/Origin-Help/Residual-Plot-Analysis)

<sup>7</sup> National Institute of Standards and Technology, *Engineering Statistics Handbook* <http://www.itl.nist.gov/div898/handbook/pmd/section4/pmd44.htm>

### 6.4.1 Rules of Thumb

To help ensure your model is valid, Table 10 outlines some rules of thumb for these statistical tests.

Table 10: Guidance for statistical tests

Statistical test	Valid range
t-statistic	Absolute value > 2
Adjusted R <sup>2</sup>	> 0.75
Relative precision calculated at 90% confidence level	Energy savings calculations are affected by the accuracy factor based on the combined relative precision of the baseline and operating energy models:  Relative precision < 25% for maximum accuracy factor  Relative precision ≥ 200% will give an accuracy factor of zero (hence a zero energy savings estimate)
Residuals check	Residuals are randomly arranged

Source: Efficiency Valuation Organisation (2014) *Statistics and Uncertainty for IPMVP*, Section 2.2; DELWP M&V Methods and Variables, Table 1

If a model fails any of these tests, it may not be a good predictor of the energy use for the project, and you may want to consider redoing the model. This could involve revising the independent variables, revising time intervals, making additional measurements, and checking for and removing any unusual events that may be skewing the data.

Besides passing these statistical tests, your model must include measurements from at least 80% of the total number of time intervals in the relevant period. When completing the model, some data points may need to be excluded to avoid skewing the data. Typical exclusions include times when site constants are not at their standard value (see [7.2 Site Constants](#)), unscheduled plant shutdowns or power failures, and periods with a known problem such as a system leak. In total, these exclusions must be less than 20% of the total measurements for the model to be considered valid.

It is key to do these statistical checks before undertaking any project work. This will give projects a chance to refine and obtain the best valid model, to increase the chance of creating VEECs.

Note that this section is not exhaustive. Other statistical tests may also be useful to ensure your model is statistically valid, such as a Q-Q plot to test normality of the data. See the external resources below for detailed guidance on statistical tests.

### 6.4.2 Further Reading

#### Program Resources

- DELWP M&V Methods and Variables, Sections 12 and 13

#### External Resources

- IPART PIAM&V Method Guide, Section D.3.3
- Efficiency Valuation Organisation (2014) *Statistics and Uncertainty for IPMVP*, Section 2
- National Institute of Standards and Technology (2012), *Engineering Statistics Handbook*
- There are many useful statistics websites online, including:
  - [statisticsshowto.com](http://statisticsshowto.com)
  - [investopedia.com](http://investopedia.com)
  - [stattrek.com](http://stattrek.com)
  - [stats.stackexchange.com](http://stats.stackexchange.com)
  - [dss.princeton.edu/online\\_help/analysis/analysis.htm](http://dss.princeton.edu/online_help/analysis/analysis.htm)

## 6.5 Energy Models in the Victorian Energy Upgrades M&V Workbook

The Baseline Model and Operating Model tabs of the *Victorian Energy Upgrades M&V Workbook* generate energy models based on the measurement data entered for the Baseline Period and Operating Period (as relevant). The workbook includes charts showing changing values of each independent variable during the model period and comparing the measured and modelled energy consumptions to visually check your model.

The workbook includes detailed statistical tests and charts described in section [6.4 Statistical Tests](#). You can analyse the model as described above to check that it meets M&V accuracy requirements, and make amendments as needed for inaccurate results.

## 7 Parameters

This section details key considerations when constructing an energy model, including choosing independent variables, site constants, time intervals, calculating the effective range of the model, accounting for interactive savings, applying a decay factor to forward savings, determining the accuracy of the model, building a normal year for forward projections, and the use of significant figures.

### 7.1 Independent Variables

Independent variables are factors that influence energy consumption for the project. They are used in energy models that use regression analysis (see [6.2 Regression Analysis](#)). Setting the right independent variables for the project is one of the most important decisions in the M&V process. The independent variables will be measured during the baseline, operating, and reporting periods, so choosing the right independent variables (and how they'll be measured) involves balancing measurement costs and model accuracy.

#### 7.1.1 Determining Independent Variables

Before starting the statistical regression, an M&V practitioner should review or undertake a basic engineering analysis of the project to establish possible independent variables. For example, an energy audit of the site may reveal key operating conditions that influence energy consumption. Table 11 outlines typical independent variables that may influence energy consumption in different M&V projects.

Independent variable measurements don't necessarily need to take place on site. For example, weather data may be obtained from an appropriate Bureau of Meteorology station. Since independent variables influence energy consumption, they may already be monitored as part of an energy management system.

Table 11: Typical independent variables to be considered in different M&V projects

M&V Project	Typical Independent Variables
Boilers, steam, and compressed air upgrades	<ul style="list-style-type: none"><li>Operating hours</li><li>Compressed air intake temperature</li><li>Boiler feedwater temperature</li><li>Compressed air, steam, or hot water use</li><li>Operating efficiency</li></ul>
HVAC projects	<ul style="list-style-type: none"><li>Operating hours</li><li>Thermal load (e.g. weather conditions, cooling/heating degree days, internal heat loads)</li><li>Operating efficiency (Coefficient of Performance or Energy Efficiency Ratio)</li></ul>
Lighting	<ul style="list-style-type: none"><li>Operating hours</li></ul>
Building retrofit	<ul style="list-style-type: none"><li>Operating hours</li><li>Weather conditions</li><li>Occupancy patterns</li><li>Activities within the building (production volumes etc)</li></ul>
Renewables or cogeneration activity	<ul style="list-style-type: none"><li>Operating hours</li><li>Weather conditions</li><li>Occupancy patterns</li></ul>

Source: OEH M&V Guide: Applications

#### 7.1.2 Number of Independent Variables

Since all independent variables included in the energy model will need to be measured during the baseline, operating, and reporting periods for your M&V project, fewer independent variables means a simpler model and lower M&V cost. Consequently, adding an independent variable to your model will add M&V costs.

You should aim to develop a model accurate enough to reliably describe energy use, while minimizing M&V costs. A simple regression model that meets the accuracy guidelines outlined in [6.2 Regression Analysis](#) is generally preferred for M&V projects.

#### 7.1.3 Checking Independent Variables

A regression analysis should align with your understanding of how the system should work. In particular, the coefficient for each independent



variable should have the correct sign—either a positive relationship (more of the independent variable results in more energy use) or a negative relationship (more of the independent variable reduces energy use).

If an independent variable does not have the sign you expect, there is likely a problem with either the model or your understanding of the physical properties of the system. Potential problems include:

- errors in the measured data
- the independent variable may be correlated with another independent variable, giving misleading results (see following section on multicollinearity)

If you encounter an unexpected sign, you should review your model to confirm that you are not over-fitting the data (see [6.2 Regression Analysis](#)). The solution will likely be to remove an independent variable from your analysis.

#### 7.1.4 Multicollinearity

In the best regression models, independent variables should have a significant relationship with the dependent variable, but not with other independent variables. A model with independent variables that are related to one another could be unstable or over-fit, meaning the model would not be a good predictor of site energy use (see [6.2 Regression Analysis](#)). A high correlation between independent variables is known as multicollinearity.

For example, highly correlated variables might include the day of the week and the number of occupants, or input and output volumes in a production line.

If you add or remove an independent variable from your model, and the coefficient of another independent variable changes significantly, this indicates multicollinearity. The best remedy for this potential pitfall is to remove one of the correlated independent variables from your model.

#### 7.1.5 Further Reading

##### Program Resources

- *ESC Activity Guidance*, Section 4.4

##### External Resources

- Efficiency Valuation Organisation (2014) *Statistics and Uncertainty for IPMVP*, Section 2
- *OEH M&V Guide: Best Practice Processes*, Section 4.1.3

- *IPART PIAM&V Method Guide*, Sections D3.2 and D5.1 to D5.7

- Statistics resources noted in [6 Energy Models](#)

## 7.2 Site Constants

Site factors that influence energy use but do not vary under normal conditions are called site constants. They are also known as static factors, static conditions, and prevailing conditions.

Site constants include production or service levels that are expected to remain the same before and after the project is implemented. For example, operating hours may be a site constant in a manufacturing plant.

If a factor that affects energy consumption is expected to change, then it is not a site constant and should be included in the model as an independent variable.

All regression models used in Victorian Energy Upgrades require at least one site constant. Table 12 outlines some typical site constants to consider for M&V applications.

**Table 12: Typical site constants for M&V projects**

M&V project	Typical Site Constants
Boilers, steam, and compressed air upgrades	<ul style="list-style-type: none"> <li>• System efficiency</li> <li>• Pressure and temperature control set points</li> <li>• Boiler blowdown rates</li> </ul>
HVAC projects	<ul style="list-style-type: none"> <li>• Temperature control set points</li> <li>• System design (e.g. number of units)</li> <li>• Conditioned/refrigerated area</li> <li>• Internal heat loads (e.g. lighting, IT)</li> </ul>
Lighting	<ul style="list-style-type: none"> <li>• Type and number of lamps</li> <li>• Lighting control system</li> </ul>
Building retrofit	<ul style="list-style-type: none"> <li>• Temperature control set points</li> <li>• Conditioned area</li> </ul>
Renewables or cogeneration	<ul style="list-style-type: none"> <li>• Installed system capacity</li> <li>• Heat conversion efficiency</li> <li>• System availability (e.g. planned and unplanned maintenance)</li> </ul>

Source: *IPART PIAM&V Method Guide*, Sections D5.1 to D5.7

Site constants should be defined with care. If a site constant changes, the baseline model may be invalidated, as it would no longer represent how



much energy would have been consumed if the project had not gone ahead.

If a site constant is temporarily not at its standard value, the affected time intervals are ineligible to use in savings calculations (see [7.3 Eligible Time Intervals](#)). These are often termed 'non-routine' events. Many M&V guides suggest adjusting energy models to account for non-routine events, usually based on engineering calculations. However, Victorian Energy Upgrades does not allow for such adjustments, and any non-routine events must be excluded from the analysis.

A project might involve a factor that would normally be considered a site constant, but that changes after the baseline period (for example, a project that increases building space). If such a project also involves an energy savings upgrade that can be temporarily switched off or set back to pre-upgrade settings (such as a control system), the baseline period may need to be established after the project is implemented (see [3.2 Baseline Period](#)). However, for most projects, including any that involve replacing old equipment, this approach will not be possible.

### 7.2.1 Further Reading

#### Program Resources

- *ESC Activity Guidance*, Section 4.7

#### External Resources

- *IPART PIAM&V Method Guide*, Sections D3.2 and D5.1 to D5.7
- *EVO IPMVP Core Concepts*, Section 7.1.4
- *OEI M&V Guide: Best Practice Processes*, Section 4.1.3

## 7.3 Eligible Time Intervals

Time intervals are relevant to the normal year (see [7.7 Normal Year](#)) and the reporting period. Their length is determined by your chosen measurement frequency (see [5.2 Duration and Frequency](#)). Time intervals must be sequential (without gaps between the intervals) and of equal length. For each time interval, a value must be assigned to every independent variable and site constant in the energy models. For time intervals in reporting periods, measurements for energy consumption must have been obtained and site constants must be at their normal values.

The time intervals for different energy sources do not need to be the same. For example, an upgrade

with electricity and gas may use daily intervals for electricity and weekly intervals for gas.

As noted in [5 Measurements](#), the number of independent variables in the model determines the minimum number of time intervals for a reporting period. Each independent variable must be measured at least six times the total number of independent variables, meaning the measurement frequency must meet or exceed this limit.

For baseline and operating periods, an eligible time interval also requires data to fit the effective range of the model (see [7.4 Effective Range](#)), with a 5% tolerance of the difference between maximum and minimum values. If the data for any of the independent variables is outside this range by more than 5%, that interval will be ineligible and excluded from the model. At least 80% of the total time intervals in the period must be included when developing baseline and operating energy models.

Projects with multiple energy sources may have difficulty aligning measurements for the different energy sources, independent variables, and site constants. The actual measurements may take place at different frequencies, provided a value can still be assigned at each time interval. You should select appropriate time intervals, and aim to align measurements with the time intervals as closely as possible. This could involve aggregating high frequency measurements, such as metered electricity measurements.

Additional data sources may also help obtain better alignment.

### 7.3.1 Further Reading

#### Program Resources

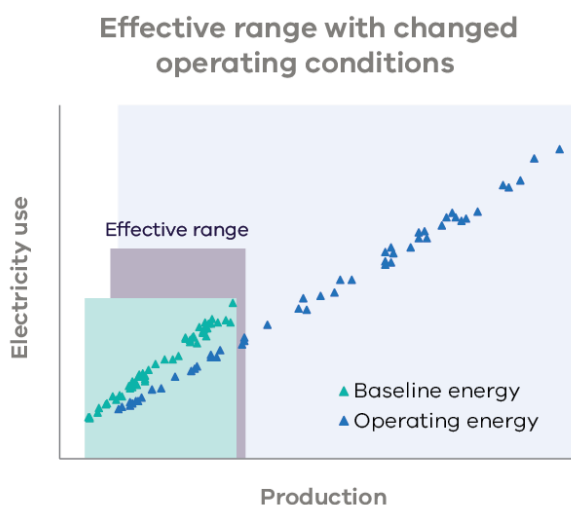
- *DELWP M&V Methods and Variables*, Section 19
- *ESC Activity Guidance*, Section 4.4.4

## 7.4 Effective Range

Effective range refers to the variations in operating conditions that can be confidently explained by your energy model. Each independent variable in your baseline and operating model has an effective range, determined by the range of measured values used to develop the model.

Effective range imposes a strict limit on the effectiveness of your model. If an independent variable has a measured value that is more than 5% outside its effective range, that measurement cannot be included in the savings calculations. This makes it very important to ensure that your model includes

measurements covering the full range of likely values of all the independent variables. Figure 13 shows the potential impact of a limited effective range. In this figure, the effective range of the baseline model is significantly smaller than that of the operating model. In the normal year, all the time intervals outside the effective range shown will be ineligible, and savings during those intervals will not be calculated.



**Figure 13: Impact of a small effective range on savings calculations**

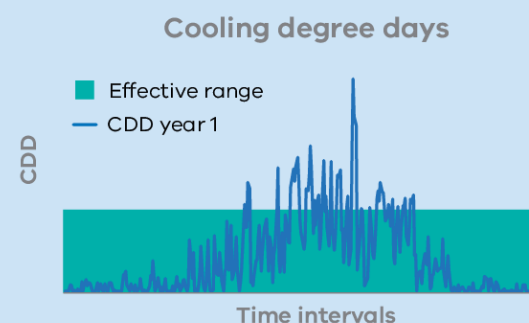
The best way to ensure that your model has a sufficient effective range is to ensure that the baseline and operating periods cover a full operating cycle for the system (see [3 Baseline, Operating, and Reporting Periods](#)). For example, if the baseline or operating period for an HVAC upgrade does not include summer conditions, any energy savings during summer will be excluded from savings calculations. The potential impact of this limitation is described in Figure 14.

In some cases, the effective range of the baseline or operating model may be increased by requesting unscheduled changes to the independent variables. For example, consider a project with production volumes as an independent variable. The site owner may temporarily vary production volume from 0% to 100% during the baseline period, so that measurements can be taken at different rates of production. The model will thus include the full range of possible values for this independent variable.

A warehouse located on an industrial site in regional Victoria upgraded their HVAC system. The measurement boundary is set to the whole building. However, the warehouse is not separately metered, so new submeters were installed to obtain baseline measurements.

Only two months of data were recorded prior to project implementation. A baseline energy model was created from the data with an independent variable of cooling degree days with an 18°C baseline. During the baseline period, cooling degree days varied between 0 and 7.9.

During the first annual reporting period, cooling degree days for the site varied from 0 to 20.5, as shown below.



The cooling degree days recorded for 52 time intervals during the reporting period were more than 8.3, which is 5% higher than the effective range of the model. These time intervals, comprising 14% of the year, are not eligible, and savings during these intervals will not be calculated.

**Figure 14: Impact of a limited effective range on a model**

#### 7.4.1 Further Reading

##### Program Resources

- *DELWP M&V Methods and Variables*, Section 19(f)
- *ESC Activity Guidance*, Section 4.4.4

##### External Resources

- *IPART PIAM&V Method Guide*, Section D.3.4

## 7.5 Interactive Energy Savings

Interactive energy savings are changes to energy consumption that take place outside the M&V measurement boundary (see [4 Measurement Boundary](#)). Interactive energy savings can be estimated using site data or engineering calculations. *DELWP M&V Methods and Variables* limits interactive energy savings to 10% of the modelled energy savings from the project.

An example of interactive energy savings is the impact of energy efficient lighting systems on HVAC energy use. If the measurement boundary for a lighting upgrade is drawn around the lighting energy use only, the HVAC energy use will be outside the boundary. Any HVAC savings will be considered interactive energy savings. These savings could be estimated using heat load calculations or another accepted approach.

Interactive energy savings should be avoided or minimised wherever possible. Interactive effects can be managed in three ways:

- **Include:** If interactive energy savings are significant, consider extending the measurement boundary to include the affected system. In this way, any impact on the system will be directly captured in the M&V model, so it is no longer an interactive effect.
- **Estimate:** Small to moderate interactive effects may be estimated within the 10% limit noted above. This may require installing sub-metering to measure changes on the affected equipment, or using engineering calculations.
- **Ignore:** If the interactive effect is negligible, it may be ignored.

In all cases, you should include justification for the treatment of interactive effects.

### 7.5.1 Further Reading

#### Program Resources

- *DELWP M&V Methods and Variables*, Section 19(f)
- *ESC Activity Guidance*, Section 4.8

#### External Resources

- *IPART PIAM&V Method Guide*, Section D.4.2
- *OEH M&V Guide: Best Practice Processes*, Section 4.1.4
- *EVO IPMVP Core Concepts*, Section 5.1

## 7.6 Decay Factor

Over time, as equipment ages, project savings will usually tail off. This reduction in savings can be estimated using a decay factor. In Victorian Energy Upgrades, decay factors are used to adjust the estimated savings from the project over a forward projection period.

Victorian Energy Upgrades allows two options for decay factors. For a simple approach, Table 2 of *DELWP M&V Methods and Variables* sets out default decay factors that can be applied to any project.

The other option is to use a persistence model. Persistence models must meet the requirements set out in *DELWP M&V Methods and Variables*, Section 17. The model must describe the decline in performance of equipment every year over its expected lifetime. It must take into account factors such as the type and use of equipment, and environmental factors that will affect its performance. An example of a model meeting these requirements is the persistence factor model developed by Low Carbon Australia and used in the NSW PIAM&V tool.<sup>8</sup>

When using a persistence model for a project that involves upgrading more than one type of equipment, you must check the persistence of all the different upgrades in the project. The persistence for the overall project is set by the upgrade that is the most conservative - that is, the one with the least persistence and quickest decay.

A project may decide to set different project boundaries to find the best decay factor possible for the project. For example, an engineering workshop upgrades an air compressor and a crusher. The independent variable for the compressor is the number of repairs in the workshop and the independent variable for the crusher is tonnes of rock processed. Instead of measuring whole site electricity consumption, both upgrades are isolated to create two separate models. This increases accuracy and allows two separate persistence models to be used, rather than a combined worst case one.

Figure 15 shows the difference between a persistence model for a particular project and the default decay factors.

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<sup>8</sup> <http://www.environment.nsw.gov.au/business/piamv-tool.htm>

A refrigeration system upgrade at a Gippsland dairy involved a new cooling tower, compressors, and pumps. To calculate decay factors for forward projected savings, the M&V practitioner used the Low Carbon Australia persistence factor model for each element of the upgrade.

The most conservative set of decay factors for the system is that for the compressor upgrade. These decay factors will allow for greater forward certificate creation than the alternative method of using the default factors from Table 2 of *DELWP M&V Methods and Variables*, as shown below.

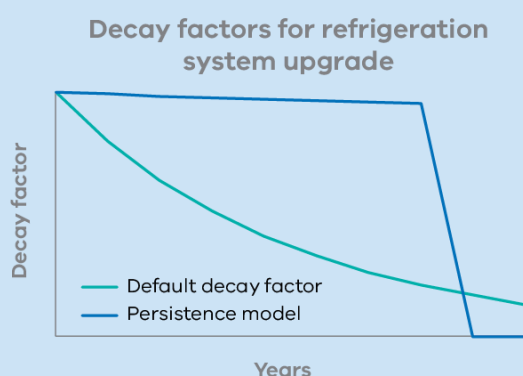


Figure 15: Persistence factor example

The decay factor means that forward projected savings always drop over time. These savings may be 'topped-up' on an annual basis (using the annual reporting calculations in *DELWP M&V Methods and Variables*) if the actual savings do not deteriorate as expected.

### 7.6.1 Further Reading

#### Program Resources

- *DELWP M&V Methods and Variables*, Section 17 and Table 2
- *ESC Activity Guidance*, Section 4.11

#### External Resources

- *IPART PIAM&V Method Guide*, Section D.4.4
- NSW Project Impact Assessment with Measurement and Verification tool: [environment.nsw.gov.au/business/piamv-tool.htm](http://environment.nsw.gov.au/business/piamv-tool.htm)

## 7.7 Normal Year

A normal year is an average year for the system. When calculating average annual savings for the project to forward create certificates, you must use the measurement data taken during the normal year. The normal year must:

- be a twelve-month period
- include values for all the independent variables used in the baseline and operating energy models, for each time interval over that period
- represent the expected mean, range, and variation of the independent variables in an average year over the forward creation period

To establish a normal year, you must define for each independent variable its expected average and range, and ensure that the normal year captures this range. A variety of data sources may inform different aspects of the normal year.

### 7.7.1 Weather-Related Variables

For systems affected by weather, normal year data could use a Typical Meteorological Year (TMY, also known as a reference meteorological year). A TMY is generated using statistical techniques based on long term weather patterns (generally 25 to 30 years). The Australian Government published TMY data for each climate zone in Victoria as the *NatHERS Climate Files 2012*. This data is available for free download through the NZ National Institute of Water and Atmospheric Research (NIWA). Older TMY data is also commercially available from ACADS-BSG. See section 7.7.4 Further Reading for links to these resources. See section 2 of the *NREL Users Manual for TMY3 Data Sets* for procedures to develop a TMY.

For HVAC systems, independent variables may include heating degree-days (HDD) or cooling degree-days (CDD). Degree-days describe the difference between average daily temperature and the temperature comfort level achieved by the HVAC system. For example, if the average temperature at a site one day is 5°C, and the HVAC system heats to 18°C, the HDD for that day would be 13. If the average temperature at a site one day is 28°C, and the HVAC system cools to 24°C, the CDD for that day would be 4.

Monthly HDD and CDD data is available from the Bureau of Meteorology. The Bureau of Meteorology also sells long-term weather data for sites across Victoria that can be used to generate TMY, HDD, and CDD data. The project site may also take



weather records that could be used to generate these data.

### 7.7.2 Site Variables

The normal year for site variables (such as production, maintenance periods, occupancy, operating hours, etc) will be based on both measurements taken before the project is implemented and the expected performance of the site after the upgrade. Establishing the normal year may involve:

- Historical measurements and forecasts for variables such as production levels, operating data, occupancy levels, etc
- Combining data from multiple operating cycles (for operating cycles shorter than a year)
- Accessing site information (such as maintenance records) to account for routine events

### 7.7.3 The Normal Year and Effective Range

As noted above, the normal year must represent the expected mean, range, and variation of the independent variables in an average year over the forward creation period. In most cases, this means that the normal year data should cover the full effective range of the model (see [7.4 Effective Range](#)).

If the effective range of the model is narrower than the range of the normal year, a significant reduction in savings could result. Normal year data that is more than 5% outside the effective range of the model may not be included in energy savings calculations.

The effective range is determined by conditions from both the baseline period and operating period. Therefore, a wide effective range in the baseline period can be negated if the operating period has a narrow effective range (and vice versa). If the effective range is limited by the operating period, the operating period may need to be extended or redone to better reflect the typical operating conditions for the forward projected period. If the baseline period is limiting the effective range, little can be done to extend the range unless the savings effect of the project can be suspended to recreate baseline conditions (see [3.2 Baseline Period](#)). Therefore, it is essential to capture data covering a sufficient range of conditions both before and after the project has been implemented.

### 7.7.4 Further Reading

#### Program Resources

- *ESC Activity Guidance*, Section 4.4.3

#### External Resources

- *IPART PIAM&V Method Guide*, Section D.4.1 and Box D.3 (gives an example of the impact of effective range on normal year calculations)
- US National Renewable Energy Laboratory (2008) Users Manual for TMY3 Data Sets: [nrel.gov/docs/fy08osti/43156.pdf](http://nrel.gov/docs/fy08osti/43156.pdf)
- Department of Industry (2012), *NatHERS climate files 2012*, available from NIWA: <https://www.niwa.co.nz/node/109982>
- Exemplary Energy Hourly Data and ERM data (available for purchase through ACADS-BSG): [members.ozemail.com.au/~acadsbsg/](http://members.ozemail.com.au/~acadsbsg/)
- Bureau of Meteorology, *Average annual & monthly heating and cooling degree days*: [bom.gov.au/jsp/ncc/climate\\_averages/degree-days/index.jsp](http://bom.gov.au/jsp/ncc/climate_averages/degree-days/index.jsp) (see the “how are the values calculated?” section for detailed advice on creating HDD and CDD data sets)

## 7.8 Significant Figures

Consistent significant figures should be maintained for energy savings calculations throughout the M&V process, to avoid overstating the accuracy of measured or estimated data.

The most appropriate significant figures to use for the M&V project will depend on the accuracy of your data. Data should be added to calculations with as much significance as is available from measurements. Results should only show significance to the level of precision of the underlying data.

For example, if energy is measured to the nearest kWh, this level of significance should be maintained throughout the M&V process.

One commonly used rule of thumb for reporting statistical results is to report calculated derivatives of the data (such as mean or standard deviation) to one more significant figure than the underlying data.

### 7.8.1 Further Reading

#### External Resources

- Mackenzie, A (2005). *Mathematics and Statistics for Life Scientists* (see section C2 Presenting Data)
- US Food and Drug Administration (2013). *ORA Laboratory Manual: Section 4 Basic Statistics and Data Presentation* (see in particular Section 4.3),



<https://www.fda.gov/ScienceResearch/FieldScience/LaboratoryManual/>

## **7.9 Parameters in the *Victorian Energy Upgrades M&V Workbook***

Independent variables and site constants for each energy source are described on the Measurements tab of the *Victorian Energy Upgrades M&V Workbook*, including how they will be monitored and measured. Enter measurements of the independent variables in the Normal Year tab (for normal year calculations), Baseline Measurements tab, Operating Measurements tab (for forward creations), and Reporting Period Values tab (for annual reporting and top-ups).

The workbook includes tabs to define a Normal Year and document the Normal Year conditions. The workbook automatically determines the Effective Range of each model based on the data you have entered. The Effective Range is detailed in the Baseline Model and Operating Model tabs. Based on this calculated effective range, Eligible Time Intervals are automatically determined, and the workbook excludes any periods that are ineligible from energy savings calculations in the Normal Year Energy Savings and Measured Annual Energy Savings tabs. Exclusions are detailed in these tabs.

Interactive Energy Savings are documented on the Interactive Savings tab of the *Victorian Energy Upgrades M&V Workbook*, with space to define the interactive savings, describe how they are calculated, and specify the calculated savings.

## 8 Equations

The equations for calculating a project's carbon dioxide equivalent to be reduced are given in *DELWP M&V Methods and Variables*. This section describes the calculations and provides some example projects.

### 8.1 Calculation Overview

There are two calculation methods that can be applied in Victorian Energy Upgrades: forward creation using an estimate of future savings, and annual creation based on annual reporting. These methods may be combined on a single project to include both a forward estimate and a 'top-up' based on annual reporting.

The equations for these calculations (detailed in *DELWP M&V Methods and Variables*) are explained below.

#### 8.1.1 Forward Creation

Figure 16 schematises the calculations needed to forward create certificates. These are described in detail in steps 1 through 3 in this section.

##### Forward creation calculations

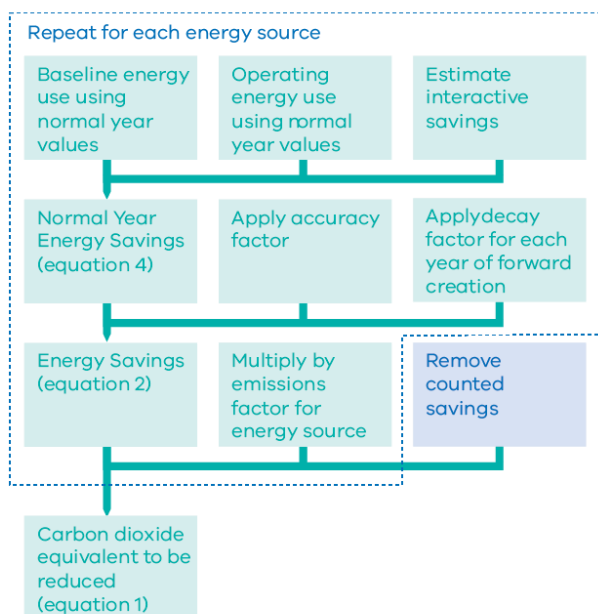


Figure 16: Forward creation calculations

#### Step 1: Calculate Normal Year Energy Savings (using Equation 4)

Requires:

- Baseline energy model (see section [6.1 Baseline and Operating Models](#))
- Operating energy model (see section [6.1 Baseline and Operating Models](#))
- Normal year (see section [7.7 Normal Year](#))
- Interactive energy savings (see section [7.5 Interactive Energy Savings](#))

First, to determine baseline energy use during a normal year, apply the normal year values for all independent variables to your baseline energy model. Do this for each time interval in the normal year.

Second, to determine operating energy use during a normal year, apply the normal year values for all independent variables to your operating energy model. Do this for each time interval in the normal year.

Third, estimate the interactive energy savings for the normal year (see [7.5 Interactive Energy Savings](#))

Finally, normal year energy savings are calculated as follows:

Normal year energy savings = the sum of (baseline energy use – operating energy use) for all time intervals in the normal year + interactive energy savings

This process can be repeated up to three times for a project.

#### Step 2: Calculate Energy Savings (using Equation 2)

Requires:

- Normal year energy savings (see above)
- Accuracy factor (see sections [5.3 Accuracy and Precision](#) and [6.4 Statistical Tests](#))
- Decay factor (see section [7.6 Decay Factor](#))

To calculate the total energy savings for the project over the forward creation period, apply your energy model's accuracy factor to the normal year energy savings calculated in step 1.

A decay factor must be applied for every year in the forward creation period. You can determine decay factors using either a persistence model or the defaults given in Table 2 of *DELWP M&V Methods and Variables*.

Repeat step 1 and 2 for each energy source and for each set of energy models in the project.

### Step 3: Calculate Carbon Dioxide to be Reduced (using Equation 1)

Requires:

- Electricity savings (the energy savings calculated in step 1 and 2 for electricity)
- Gas savings (the energy savings calculated in step 1 and 2 for gas)
- Renewable energy savings (the energy savings calculated in step 1 and 2 for renewable energy)
- Counted savings (see section [8.6 Counted Savings](#))

The counted savings for a project include both the certificates that have previously been created for the project (using this forward creation method), and any certificates created within the project's measurement boundary using other Victorian Energy Upgrades methods (such as certificates created for lighting upgrades using deemed certificate calculations).

For each energy source, apply the appropriate emissions factor from *DELWP M&V Methods and Variables* to the savings calculated for that energy source. This gives the total emissions savings for each energy source.

The carbon dioxide equivalent to be reduced is the total emissions savings for each energy source, minus any savings that have already been counted for the project (counted savings).

#### 8.1.2 Annual Reporting

Figure 17 schematises the calculations needed to forward create certificates. These are described in detail in steps 1 through 3 in this section.

### Annual reporting and top-up calculations

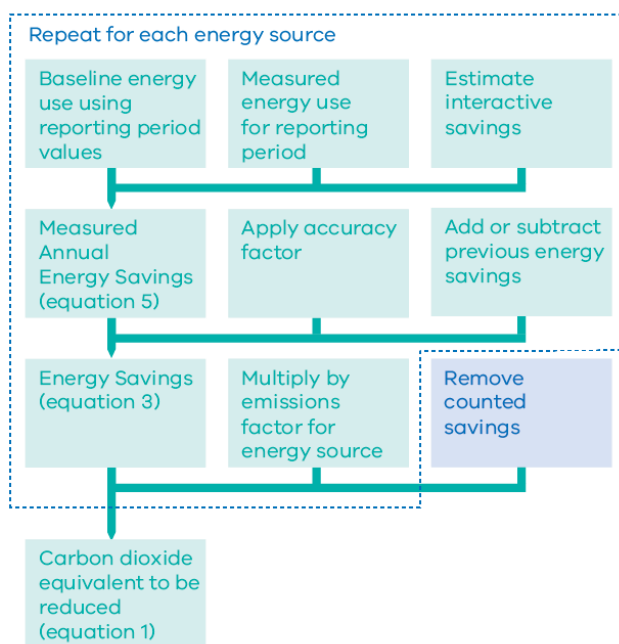


Figure 17: Annual reporting and top-up calculations

### Step 1: Calculate Measured Annual Energy Savings (using Equation 5)

Requires:

- Baseline energy model (see section [6.1 Baseline and Operating Models](#))
- Measurements of energy use and independent variables during the reporting period (see sections [3.4 Reporting Period](#), [5 Measurements](#), and [7.1 Independent Variables](#))

First, to determine baseline energy use in the reporting period, apply the reporting period values for all independent variables to your baseline energy model. Do this for each time interval in the reporting period.

Second, estimate the interactive energy savings for the reporting period.

Measured annual energy savings are calculated as follows:

Measured annual energy savings = the sum of (baseline energy use – measured energy use) for all time intervals in the reporting period + interactive energy savings

## Step 2: Calculate Energy Savings (using Equation 3)

Requires:

- Measured annual energy savings (see above)
- Accuracy factor (see sections [5.3 Accuracy and Precision](#) and [6.4 Statistical Tests](#))
- Previous energy savings

Previous energy savings describes the cumulative savings for a given energy source for all previous reporting periods.

To calculate the total energy savings for the project (including the current reporting period), apply your energy model's accuracy factor to the measured annual energy savings calculated in step 1, and add previous energy savings.

Repeat step 1 and 2 for each energy source and set of energy models in the project.

## Step 3: Calculate Carbon Dioxide to be Reduced

Requires:

- Electricity savings (the energy savings calculated in step 1 and 2 for electricity)
- Gas savings (the energy savings calculated in step 1 and 2 for gas)
- Renewable energy savings (the energy savings calculated in step 1 and 2 for renewable energy)
- Counted savings (see section [8.6 Counted Savings](#))

The counted savings for a project include both the certificates that have previously been created for the project (using the forward creation or annual reporting method), and any certificates created within the project's measurement boundary using other Victorian Energy Upgrades calculations.

For each energy source, apply the appropriate emissions factor from *DELWP M&V Methods and Variables* to the savings calculated for that energy source. This gives the total emissions savings for each energy source.

The carbon dioxide to be reduced is the total emissions savings for each energy source, minus any savings that have already been counted for the project (counted savings).

### 8.1.3 Forward Creation with 'Top-Up'

This method is a combination of the two methods, using forward projection to estimate future savings, and annual reporting to calculate the actual savings

during the reporting period. Once the cumulative annual reporting savings exceeds those forward-projected, certificates can be created to 'top-up'.

First, complete forward creation following the steps in section [8.1.1 Forward Creation](#).

Next, complete annual reporting following the steps in section [8.1.2 Annual Reporting](#).

The counted savings for a project include both the certificates that have previously been created for the project (using the forward creation or annual reporting method), and any certificates created within the project's measurement boundary using other Victorian Energy Upgrades calculations.

## 8.2 Equation 5: Measured Annual Energy Savings

Measured annual energy savings (MAES) is the difference between the actual measured energy use and the modelled baseline energy use during a reporting period. It is used for the annual reporting and 'top-up' methods. Measured annual energy savings is defined by Equation 5 in *DELWP M&V Methods and Variables*:

$$\text{measured annual energy savings} = \sum_t (E_{BM,t} - E_{meas,t}) + E_{int}$$

where:

- $t$  is an eligible time interval in the reporting period
- $E_{BM,t}$  is the energy consumption for  $t$  given by the baseline energy model
- $E_{meas,t}$  is the measured energy consumption for  $t$
- $E_{int}$  is the total interactive energy savings for the project in the reporting period

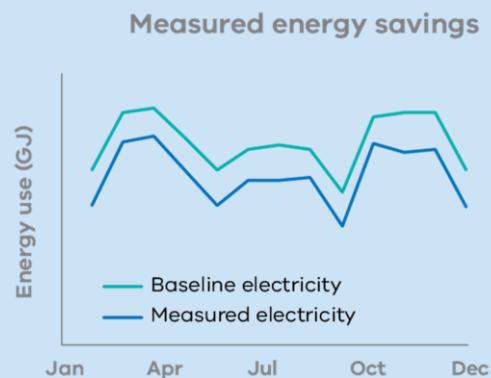
### 8.2.1 MAES in the Victorian Energy Upgrades M&V Workbook

Use the MAES tab to complete this calculation in the *Victorian Energy Upgrades M&V Workbook*. The calculation should complete automatically once you have entered Normal Year, Baseline Period, Reporting Period, and Interactive Energy Savings data for the project.

Figure 18 provides a case study for a typical use of this equation.

An agricultural products manufacturer in south western Victoria implemented a project to automate paint and powder coating lines, upgrade motors and lighting controls, and replace a gas boiler with a heat pump.

The baseline energy model for the project is developed using a regression analysis of existing energy use and operational data. The independent variables for the model are operating hours (for electricity) and heating degree days (for gas energy use). Twelve months after the project is implemented, all reporting period measurements have been obtained. The baseline models for gas and electricity are populated with these measurements to give the baseline energy use for each time interval. There are no interactive energy savings for the project, as the whole site is included in the measurement boundary.



Total energy use over the reporting period:

Energy source	Baseline	Measured	Interactive
Electricity	22529 MWh	21216 MWh	0 MWh
Gas	4586 GJ	1277 GJ	0 GJ

Measured annual energy savings (electricity) = 22,529 – 21,216 + 0 = 1,313 MWh

Measured annual energy savings (gas) = 4,586 – 1,277 + 0 = 3,309 GJ

Figure 18: Case study - measured annual energy savings

### 8.3 Equation 4: Normal Year Energy Savings

Normal year energy savings (NYES) is the difference between the energy consumption predicted by the baseline energy model and that predicted by the operating energy model for a normal year. The normal year savings is used to estimate the typical annual savings from the project over a future period, and is used in forward creation (see [7.7 Normal Year](#)).

Normal year energy savings is defined by Equation 4 in *DELWP M&V Methods and Variables*:

$$\text{normal year savings} = \sum_t (E_{BM,t} - E_{OM,t}) + E_{int}$$

where:

- $t$  is an eligible time interval in the normal year
- $E_{BM,t}$  is the energy consumption for  $t$  given by the baseline energy model
- $E_{OM,t}$  is the energy consumption for  $t$  given by the operating energy model
- $E_{int}$  is the total interactive energy savings for the project in the normal year

#### 8.3.1 NYES in the *Victorian Energy Upgrades M&V Workbook*

Use the NYES tab to complete this calculation in the *Victorian Energy Upgrades M&V Workbook*. The calculation should complete automatically once you have entered Normal Year, Baseline Period, Operating Period, and Interactive Energy Savings data for the project.

Figure 19 provides a case study for a typical use of this equation.



A cold storage facility in Melbourne redesigned and upgraded their refrigeration and lighting systems. They wish to forward create certificates.

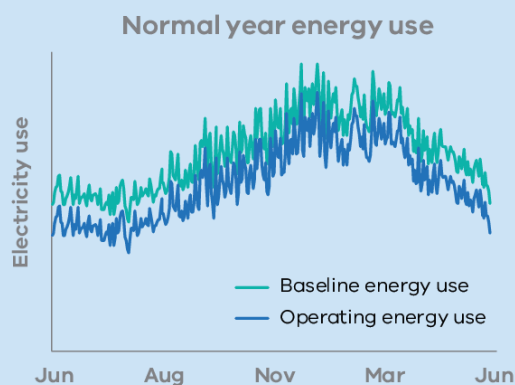
The measurement boundary is set at the whole-site level. Electricity is the only energy source, and the only independent variable for the baseline and operating energy models is cooling degree-days, with a base temperature of 3°C.

The energy model formulae for the site are:

$$\text{Baseline energy use} = 25.11 + 1.753 \times \text{CDD}$$

$$\text{Operating energy use} = 19.35 + 1.769 \times \text{CDD}$$

The normal year is established using cooling degree-day data from a nearby Bureau of Meteorology site.



The total baseline energy use in the normal year is 17,042 MWh. The total operating energy use is 15,013 MWh. There are no interactive energy savings from the site.

$$\text{Normal year energy savings} = 17,042 - 15,013 = 2,029 \text{ MWh}$$

Figure 19: Normal year energy savings case study

## 8.4 Equation 3: Energy Savings Using Annual Creation or 'Top-Up' Method

This equation calculates the total energy savings during a reporting period for an annual creation or top-up.

The energy savings during a reporting period is the difference between energy consumption predicted

by the baseline energy model and the actual measured energy consumption. It is defined by Equation 3 in *DELWP M&V Methods and Variables*:

$$\text{energy savings} = \text{measured annual energy savings} \times AF \pm \text{previous energy savings}$$

where:

- measured annual energy savings is calculated using Equation 5
- AF is the accuracy factor determined using Table 1 in *DELWP M&V Methods and Variables*, where the "relative precision" means the relative precision of the measured savings at 90% confidence level
- previous energy savings is the total amount of energy savings calculated for the previous reporting period (if any) using this equation, including any negative energy savings

### 8.4.1 MAES in the Victorian Energy Upgrades M&V Workbook

Use the Energy Savings (MAES) tab to complete this calculation in the *Victorian Energy Upgrades M&V Workbook*.

Figure 20 in the following section provides an example of a typical M&V project using the top-up calculation.

## 8.5 Equation 2: Energy Savings Using Forward Creation method

This equation estimates the total energy savings for the project over a forward creation period of up to 10 years.

The forward energy savings is the sum of the normal year energy savings for each year over the forward creation period, adjusted for the accuracy of the model and the decay of savings over time. It is defined by Equation 2 in *DELWP M&V Methods and Variables*:

$$\text{energy savings} = \sum_i (\text{normal year savings} \times AF \times DF_i)$$

where:

- $i$  is a year of the forward creation period for the project (up to 10 years, as determined by the set of decay factors)
- normal year savings is calculated using Equation 4
- AF is the accuracy factor
- $DF_i$  is the decay factor for year  $i$

### 8.5.1 NYES in the *Victorian Energy Upgrades M&V Workbook*

Use the Energy Savings (NYES) tab to complete this calculation in the *Victorian Energy Upgrades M&V Workbook*. The calculation should complete automatically once you have checked the Normal Year Energy Savings calculation for the project.

Figure 20 outlines an example of forward creation in a typical M&V project.

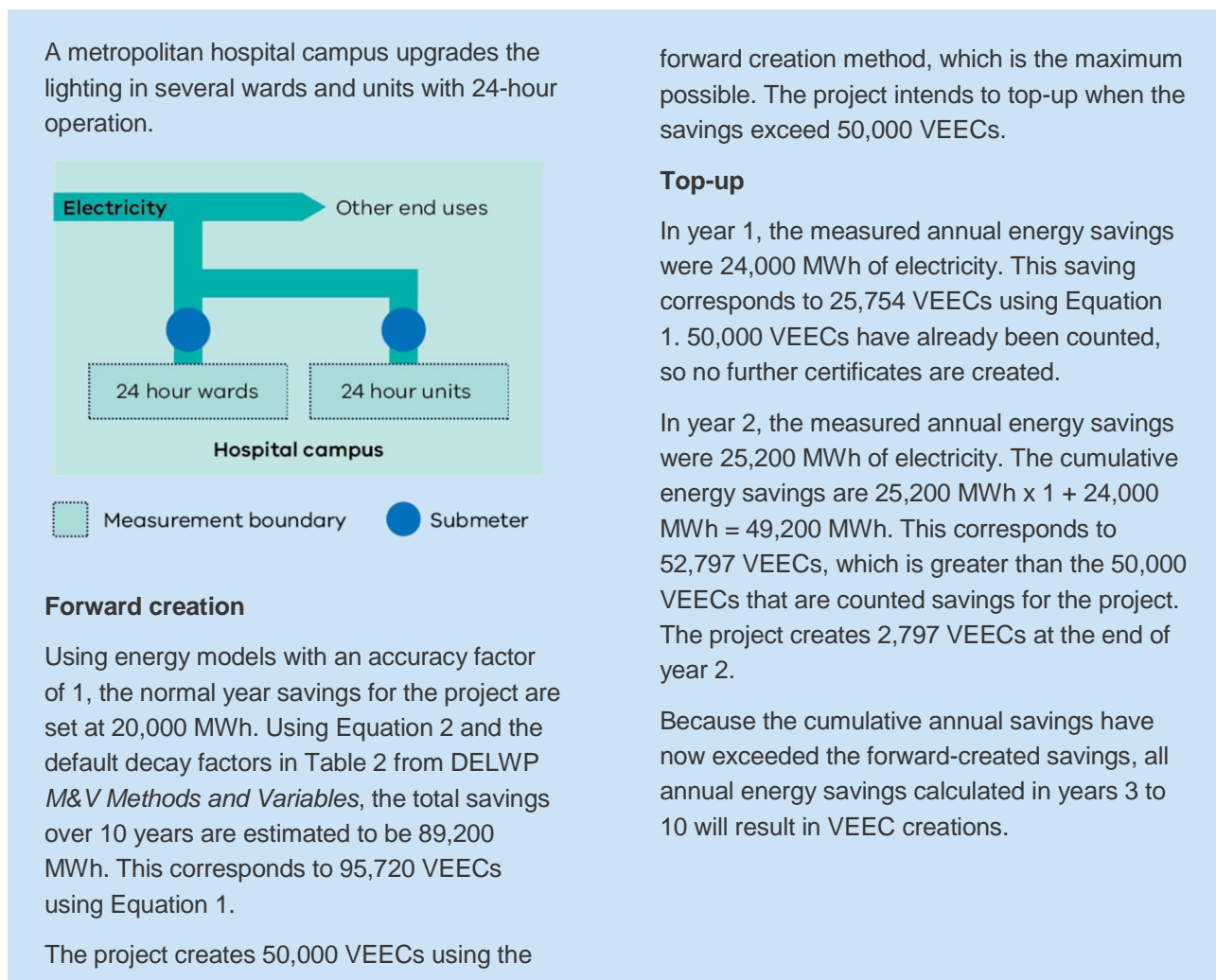


Figure 20: Example top-up project

## 8.6 Counted Savings

The counted savings for the project must be determined before calculating the carbon dioxide equivalent to be reduced. Counted savings are the certificates that have already been created for the project, or for other projects that are included within the measurement boundary (see [4 Measurement Boundary](#)). Counted savings may be reduced in proportion to the eligible time intervals (see [7.3 Eligible Time Intervals](#)) in the normal year, and in proportion to the number of years that the savings and remaining reporting periods coincide.

See example in Figure 21 below.

### Adjusting counted savings for eligible time intervals in the normal year

An M&V project intends to forward create VEECs. Within the project boundary, 10,000 VEECs were also created under a second activity after the end of the baseline period. For the M&V project, 80% of time intervals in the normal year were eligible. The VEECs from the second activity need to be subtracted from the savings from the M&V activity as counted savings, using Equation 1. However, the 10,000 VEECs may be adjusted to  $80\% \times 10,000 = 8,000$  VEECs.

### Adjusting counted savings for remaining reporting periods

An M&V project is creating VEECs using the annual reporting method. Four years after the project is installed, a lighting retrofit is installed within the measurement boundary using a different Victorian Energy Upgrades schedule. The lifetime of this new activity is set at 8.5 years.

The maximum period of annual creation for the M&V project is 10 years. Therefore, there are six remaining eligible reporting periods (years 5 to 10) in the original M&V project.

The counted savings from the lighting retrofit may be adjusted by the proportion of the lighting retrofit savings that coincides with the remaining reporting periods for the M&V project – 6 years

out of the 8.5-year lifetime, or 70%.

Figure 21: Adjusting counted savings examples

Table 13 overleaf outlines different types of counted savings that may arise in M&V projects.

### 8.6.1 Counted Energy Savings in the Victorian Energy Upgrades M&V Workbook

Use the Counted Energy Savings tab in the *Victorian Energy Upgrades M&V Workbook* to document counted savings for your project.

## 8.7 Equation 1: Carbon Dioxide Equivalent to be Reduced

The final equation in Victorian Energy Upgrades M&V savings calculations is the reduction in carbon dioxide equivalent. A reduction of one tonne of carbon dioxide equivalent corresponds to one VEEC. The savings for each energy source affected by the project are calculated separately using Equation 2 (for forward creations) or Equation 3 (for annual reporting or top-ups). Once these savings are known, the total carbon dioxide equivalent for the project is defined by Equation 1 in *DELWP M&V Methods and Variables*:

$$\begin{aligned} \text{carbon dioxide equivalent} &= \text{electricity savings} \times \text{electricity emissions factor} \times \text{RF} \\ &+ \text{gas savings} \times \text{gas emissions factor} \\ &+ \text{renewable energy savings} \times \text{renewable emissions factor} \\ &- \text{counted savings} \end{aligned}$$

where:

- Electricity savings is calculated in MWh using Equation 2 or 3
- RF is the Regional Factor, which is 0.98 if the project is undertaken in metropolitan Victoria and 1.04 if the project is undertaken in regional Victoria (as per Schedule 27 of the VEET Regulations 2008)
- Gas savings is calculated in GJ using Equation 2 or 3
- Renewable energy savings is calculated using Equation 2 or 3
- Counted savings is the certificates that have already been created for this project and any other activities undertaken within the measurement boundary after the end of the baseline period.

Table 13: Counted savings examples

Project type	Source of counted savings	Calculating VEECs	Example
Forward creation with top up	Forward creation	Top up VEECs can only be created when the total savings (calculated with Equation 3) exceed the forward created savings (calculated with Equation 2)	<p>Legend:   <span style="color: teal;">■</span> Previously created   <span style="color: lightteal;">■</span> Counted savings   <span style="border: 1px dashed black; display: inline-block; width: 10px; height: 10px;"></span> New VEECs</p> <p>The chart shows a single teal bar for 'Forward created' savings. To its right, under 'Annual creation', are three stacked bars. Each bar has a teal base of height 1 and a lightteal top of height 2. The third bar also has a dashed black box on top of height 3, representing new VEECs.</p>
Multiple forward creations	Previous forward creations	VEECs from previous forward creations are subtracted from VEECs from latest forward creation	<p>The chart shows a teal bar for 'Initial Forward creation' and a taller lightteal bar for 'Second Forward creation'.</p>
Annual creation in the second and subsequent years	VEECs annually created	Calculate the cumulative total energy savings and subtract the VEECs already created. VEECs are awarded when the result is a positive number	<p>The chart shows two stacked bars under 'Annual creation'. The first bar has a teal base of height 1. The second bar has a teal base of height 1 and a lightteal top of height 2.</p>
Forward creation plus an activity under another Schedule in the measurement boundary after the end of the baseline period	VEECs created via another Schedule	Subtract the VEECs created under the other activity from the total reduced. The counted savings may be adjusted. See example in Figure 21 below.	<p>The chart shows two bars. The first is a teal bar labeled 'Created by other method'. The second is a lightteal bar labeled 'Created by this method'.</p>
Annual creation plus an activity under another Schedule in the measurement boundary after the end of the baseline period	VEECs created via another Schedule	Subtract the VEECs created under the other activity from the total reduced. The counted savings may be adjusted. See example in Figure 21 below.	

### 8.7.1 GHG Savings in the Victorian Energy Upgrades M&V Workbook

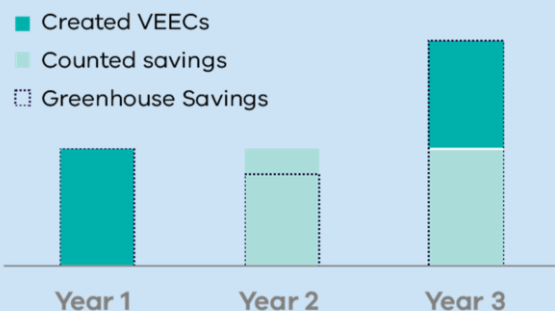
Use the GHG savings tab in the *Victorian Energy Upgrades M&V Workbook* to calculate the number of certificates for the project. The calculation should complete automatically based on the information you have entered for the project.

Figure 22 provides an example of this calculation, showing the treatment of counted savings in a typical project.

A project involving many small improvements to a steam distribution system is using the annual creation method to claim certificates. The baseline energy model is an estimate of the mean with 18% relative precision, giving an Accuracy Factor of 0.9.

The energy savings for the project over three years is shown below.

#### Greenhouse Savings and VEEC creation



In year 1, the measured savings (Equation 5) was 55,000 GJ of natural gas. The energy savings (Equation 3) are  $55,000 \text{ GJ} \times 0.9 = 49,500 \text{ GJ}$ . 2,734 VEECs are created using

Equation 1, based on the emissions factor for natural gas.

In year 2, a steam leak caused energy consumption to exceed the baseline. The measured savings (Equation 5) were -12,000 GJ. The previous energy savings are 49,500 GJ as calculated above. The energy savings (Equation 3) were  $-12,000 \text{ GJ} \times 0.9 + 49,500 \text{ GJ} = 38,700 \text{ GJ}$ . No VEECs can be created as there are no savings above those already claimed.

In year 3, the leak has been found and repaired. The measured savings were 62,000 GJ. The previous energy savings were 38,700 GJ. The energy savings were therefore  $62,000 \text{ GJ} \times 0.9 + 38,700 = 94,500$ . This corresponds to 5,219 VEECs, but 2,734 have already been created (they are 'counted savings' in Equation 1) and cannot be created again. The additional certificates can be created at the end of year 3:  $5,219 - 2,734 = 2,485$  VEECs.

Figure 22: Example of calculating carbon dioxide equivalent to be reduced



## 9 Glossary

Term	Meaning
Accuracy factor	A factor applied to calculated energy savings based on the relative precision of the energy model
Adjusted R <sup>2</sup>	A value that reveals how well a statistical model fits the measured data
Baseline energy model	The energy model created using measurements from the baseline period
Baseline period	A period of time, ranging from less than one week to more than one year, that takes place before the project is implemented and ends within 24 months of the start of the project
Decay factor	An estimate of savings reductions over time
Deemed method	A method of calculating energy savings using deemed savings
Dependent variable	In Victorian Energy Upgrades M&V, the dependent variable is energy use
Effective range	The variations in operating conditions that can be confidently explained by your energy model, determined by the range of measured values of all independent variables
ESC	Essential Services Commission
Estimate of the mean	An alternative to regression analysis based on average energy consumption over the measurement period
EVO	Efficiency Valuation Organisation
Forward creation	A process for estimating future savings of an energy savings project
Forward creation period	The future period over which we want to estimate savings
HVAC	Heating, Ventilation, and Air Conditioning
Independent variable	In Victorian Energy Upgrades M&V, independent variables are the physical factors that impact energy use
Interactive energy savings	Any energy changes that take place outside the measurement boundary
IPMVP	International Measurement and Verification Protocol
M&V	Measurement and Verification
Measurement boundary	A consistent reference point to measure energy consumption before and after project implementation
Multicollinearity	A high correlation between independent variables
Normal year	An average year for the system after the energy savings project is implemented
Operating energy model	The energy model created using measurements from the operating period
Operating period	A period that takes place within two years of the implementation of the project, used to establish an operating energy model
Regression analysis	A statistical model that describes the relationship between a dependent variable and one or more independent variables
Relative precision	Describes the relative range of measured values of the dependent variable
Reporting period	One of up to ten year-long periods in the project's life counted from the date the project is implemented and commissioned
Residuals check	A statistical test of a model's residuals, i.e., the difference between measured and predicted values of the dependent variable

Site constant	A site factor that influences energy use but does not vary under normal conditions. Also known as static factors, static conditions, and prevailing conditions
Time interval	Data is collected by taking measurements at regular time intervals. Each time interval will consist of a set of measurements for each variable in an energy model
TMY	Typical Meteorological Year
t-statistic	A value that indicated an independent variable's impact on the overall energy model
VEEC	Victorian Energy Efficiency Certificates. 1 VEEC = 1 tonne of CO <sub>2</sub> -equivalent savings
VEET	Victorian Energy Efficiency Target / Victorian Energy Upgrades

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