The Department of Climate Change, Energy, the Environment and Water

# Measurement and verification demonstration project

Supermarket: Installation of a voltage optimisation unit and variable speed drives

August 2024

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

**Published by** NSW Department of Climate Change, Energy, the Environment and Water

dcceew.nsw.gov.au

**Title** Measurement and verification demonstration project

**Sub-title** Supermarket – Installation of a voltage optimisation unit and variable speed drives

**First published** August 2024

**ISBN** 978-1-923076-41-9

# Contents

# Step-by-step M&V activities

This measurement and verification (M&V) demonstration project shows how to effectively measure and verify the impact of process changes due energy efficiency upgrades in a supermarket using the *Guide to measurement and verification of energy efficiency projects in Australia* (M&V Guide), module 1 and module 2.

Each of the 16 steps outlined in figure 1 and detailed in section 2, module 1 of the M&V Guide will be discussed in the following sections.

The appendices to this demonstration project document outline the process that the supermarket went through to create Energy Savings Certificates (ESCs) in accordance with the requirements of the NSW Energy Savings Scheme Rule (ESS Rule), as well as the accuracy calculations of the selected baseline measurement period. The appendices also Include the M&V plan and M&V report.

## Project background

Supermarkets are often high consumers of energy with heating, ventilation and air conditioning (HVAC), lighting and refrigeration contributing significantly to the electricity bill.

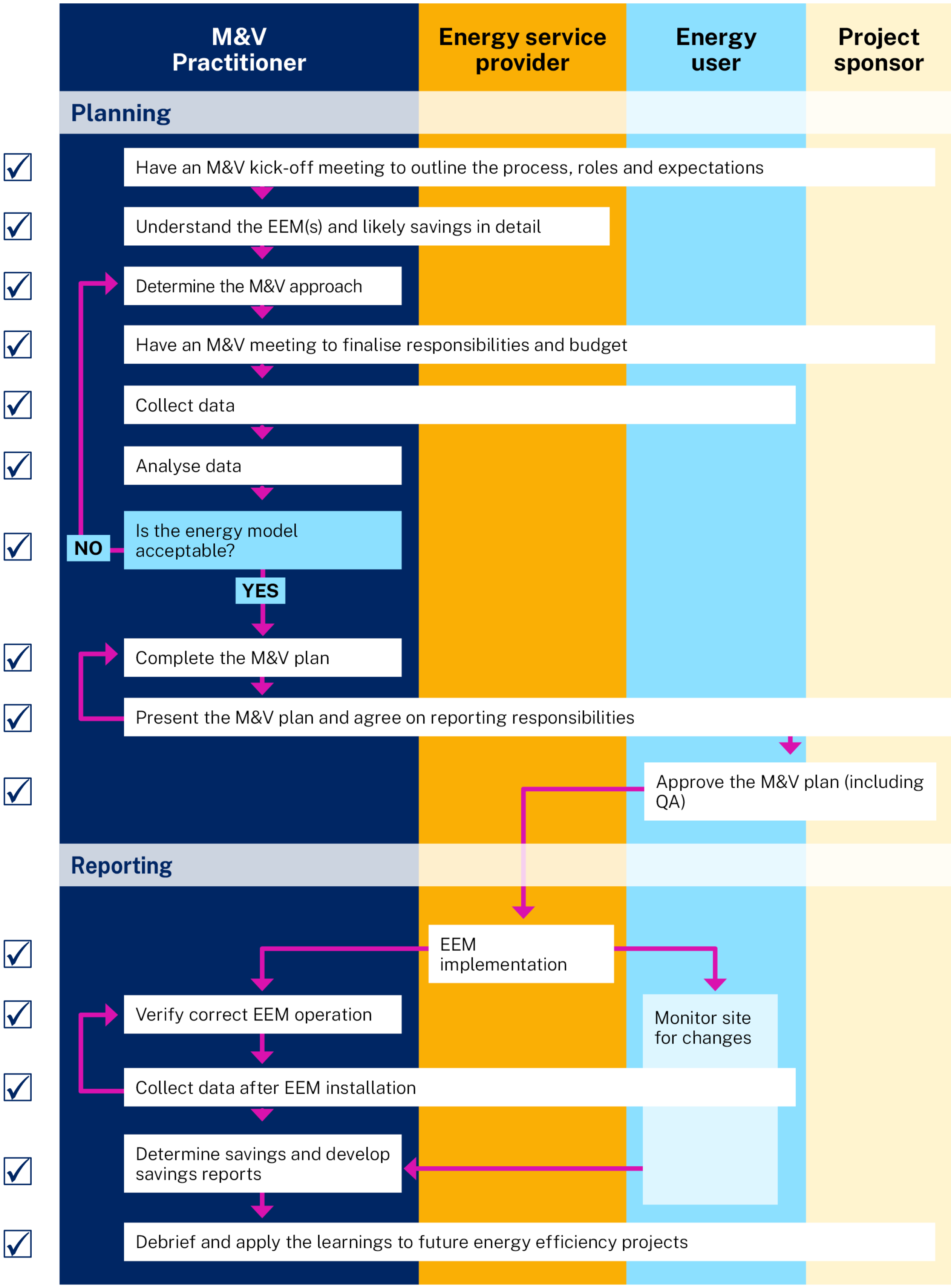
This demonstration project shows how a supermarket implemented an effective M&V process to capture savings that resulted from their investment in energy efficiency within the store.

The energy efficiency measures (EEMs) implemented included:

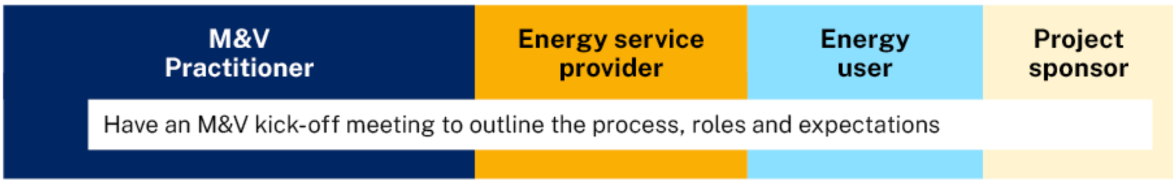
- installing a voltage optimisation (VO) unit on the power supply to the site
- fitting variable speed drives (VSDs) to the lead compressors of the refrigeration units.

These upgrades were expected to save electricity consumption but needed to be confirmed through a proper M&V process.

**Figure 1** Step-by-step approach to maximise the value of M&V



# Step 1 M&V kick-off meeting (outlining the process, roles and expectations)




A 'kick off' meeting is usually held to establish a common understanding among participants of the M&V process for the energy efficiency project at hand.

In this example, M&V activities were initiated by the supermarket management (energy user), following the decision to install a VO unit and VSDs on the refrigeration units.

The kick-off meeting involved several stakeholders including the:

- supermarket management
- energy services provider
- M&V practitioner - Accredited Certificate Provider (ACP).

In some cases, the kick off meeting would include the external financier, however in this example the upgrades were being funded by the supermarket.

Based on the energy efficiency projects being proposed, the energy services provider estimated the annual energy savings to be 133 MWh. At an average electricity tariff of $0.20/kWh, the annual energy bill savings would be $26,000. Assuming these annual energy saving were achieved over the expected 8 year life of the equipment, the energy bill savings would be over $200,000.

The energy services provider recommended an M&V process to enable the creation of Energy Saving Certificates (ESCs) under the NSW Project Impact Assessment M&V (PIAM&V) method. The process to create ESCs was explained to the supermarket management including timeline requirements and how the ESCs proceedings could be then used to offset some of the upgrade costs. Using the savings estimates as a guide, the M&V practitioner advised ESCs revenue would be $33,800 (at an assumed ESC price of $30 per ESC) or approximately $27,000 after broker and registration fees. This would be an added benefit to the cost savings resulting from the EEM.

The M&V practitioner cautioned that:

- the estimates of savings by the energy services provider may not be accurate and actual savings determined through M&V could be significantly different
- the ESC price may change and can be unpredictable
- broker fees and registration fees would reduce the overall amount received by the supermarket by around $5 per certificate.

The M&V practitioner discussed the importance of ongoing monitoring to ensure the continuity of savings. Annual savings could drop considerably without active ongoing monitoring.

The M&V practitioner requested the supermarket management commits to several activities including:

- providing the M&V practitioner with a letter of authority to directly collect electricity consumption data from the electricity retailer including historical data
- monitoring the site for changes in operating hours, to the floor area, to energy-using equipment and any unusual (non-routine) events such as unexpected shutdowns
- alerting the M&V practitioner of any changes on site that may impact energy consumption
- consulting with the M&V practitioner well before any planned changes to the site are implemented
- installing additional metering or deferring planned changes if needed to create certificates.

The supermarket management advised that it had no planned changes for the site and that it would keep the M&V practitioner informed if any changes were considered. They also agreed that ongoing monitoring to verify the persistence of savings was important.

In the kick-off meeting, it was agreed that the energy services provider would:

- provide the M&V practitioner with their energy audits or any similar documentation that identified the proposed upgrades and estimated the amount of energy savings
- share any data collected on-site energy use with the M&V practitioner
- commence the energy efficiency upgrades works only once the M&V practitioner had advised that a suitable energy baseline period had been developed
- notify the M&V practitioner once the upgrades were implemented and commissioned.

The site also used natural gas for heating domestic hot water used in the delicatessen, bathrooms and fruit and vegetable preparation area. The M&V practitioner advised there was no need to monitor the gas use as it would be unaffected, either directly or indirectly, by the planned upgrades.

The M&V practitioner enquired about the supermarket management's expectations around the accuracy of savings determination. The supermarket management did not have any expectations as long as it was possible to create ESCs.

The budget for producing an M&V plan was estimated to be $5,000. The supermarket management accepted this initial estimate provided it be finalised once the baseline period data had been analysed.

**Checklist of activities and outcomes with notes where there are deficiencies**

- ☑ All parties understand the EEM in broad terms.
- ☑ The energy user understands what M&V is, the value it provides, and how it is done. Examples of previous successful M&V plans and reports can be useful here.

  *Example plans and reports were not presented in the initial meeting.*
- ☑ All parties have a clear understanding of their roles and responsibilities, what is expected of them and when.
- ☑ Agreement on timelines including allowing time to collect baseline data, to develop a robust energy model and to install the EEMs.
- ☑ Agreement on M&V practitioner's access to the site.
- ☑ Preliminary agreement on the level of accuracy required for savings determination.
- ☑ Discussion on the importance of persistence of savings and the duration of M&V activities required to ensure persistent savings.
- ☑ Preliminary discussion on M&V budget.
- ☑ Available data and what data could potentially be missing has been identified.
- ☑ All parties understand likely future changes at the site that will impact on energy consumption including understanding what constitute normal and abnormal operation.

# Step 2 Understand the EEMs and likely savings in detail


This step involves the M&V practitioner liaising with the energy services provider to understand the specifics of the site and the EEM.

## Site electricity consumption

The M&V practitioner obtained the electricity interval data. This data covered the period from January 2018 to the end of May 2019.

The site's annual electricity consumption was 932 MWh in 2018. Electricity use was slightly lower in winter than in summer. Electricity use in the first 5 months of 2019 was nearly 5% lower than the comparable period in 2018. This was concerning as it could have a material impact on the determination of savings.

## Equipment impacted by the EEMs

The equipment that would be impacted by the EEMs was:

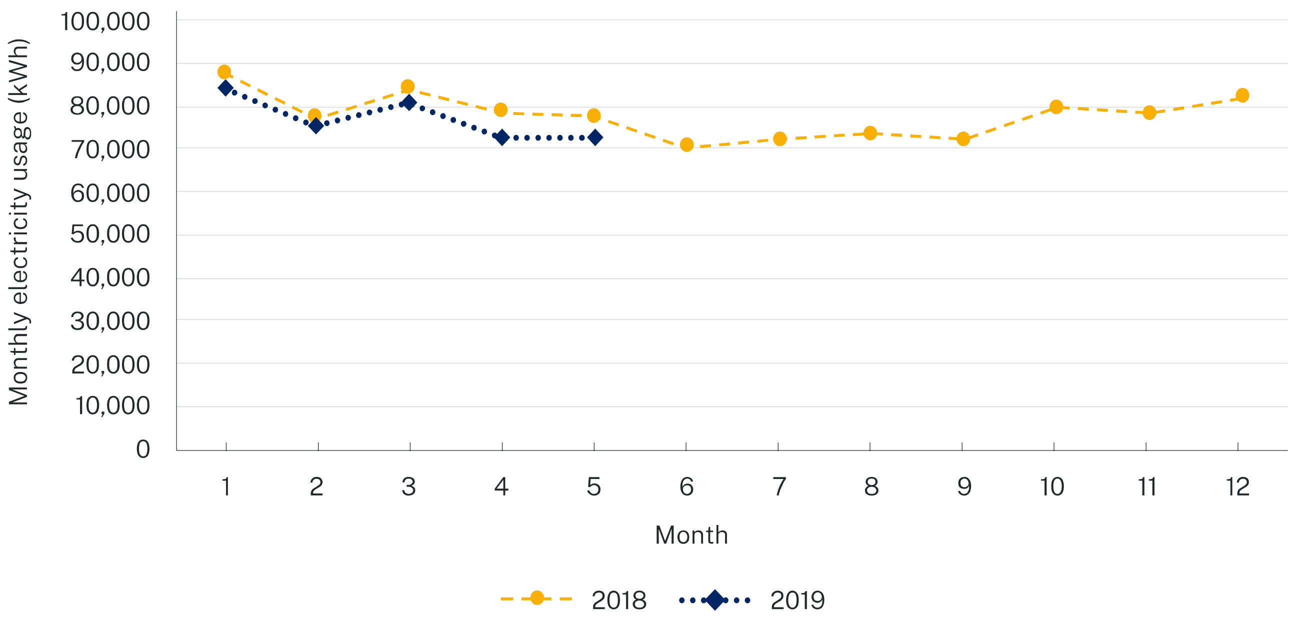
- VO unit installed on the site's mains electricity supply
- the refrigeration compressor units would be impacted by the VSD upgrades.

The refrigeration units were comprised of both medium temperature and low temperature systems. The medium temperature system had 4 compressors and 4 capacity regulators. The low temperature systems had 3 compressors.

## Energy use of the equipment subject to the EEMs

To capture the savings from both upgrades, the electricity consumption of the whole site was considered when determining savings. Figure 2 shows the monthly site electricity consumption before the upgrades.

**Figure 2** Average monthly electricity consumption before the upgrade



## How the EEMs save energy

Voltage optimisation (VO) reduces the electricity consumption of electrical loads that directly draw alternating current power without passing through a transformer or inverter.

When the voltage exceeds the design operating voltage, the VO unit can save power by reducing the voltage to the design voltage without compromising equipment lifetime, reliability or service delivery. Typically, voltages are around 10 to 15 volts higher than the designed operating voltage for 230 volt systems. In this example, the VO unit was installed on the power supply to the site.

Variable speed drives (VSDs) save on the energy consumed by an electric motor by reducing its speed reducing the amount of 'work' done by the motor. In this example, the existing compressors were somewhat oversized and cycled on and off. The fitting of VSDs, in combination with changing the control parameters used in the refrigeration cycle, enabled the compressors to run continuously with a reduced pressure rise across the compressor. This saves energy by bringing the evaporator and condenser temperatures closer together and improving the refrigeration cycle coefficient of performance.

The use of sensors to monitor the refrigeration system can be used to control motor speed maintaining more even operation, potentially resulting in larger energy savings at times of low demand.

## Expected energy savings

The energy services provider estimated the expected annual savings to be 133 MWh, or 14.3%, of annual electricity consumption.

## Expected costs of implementing the EEMs

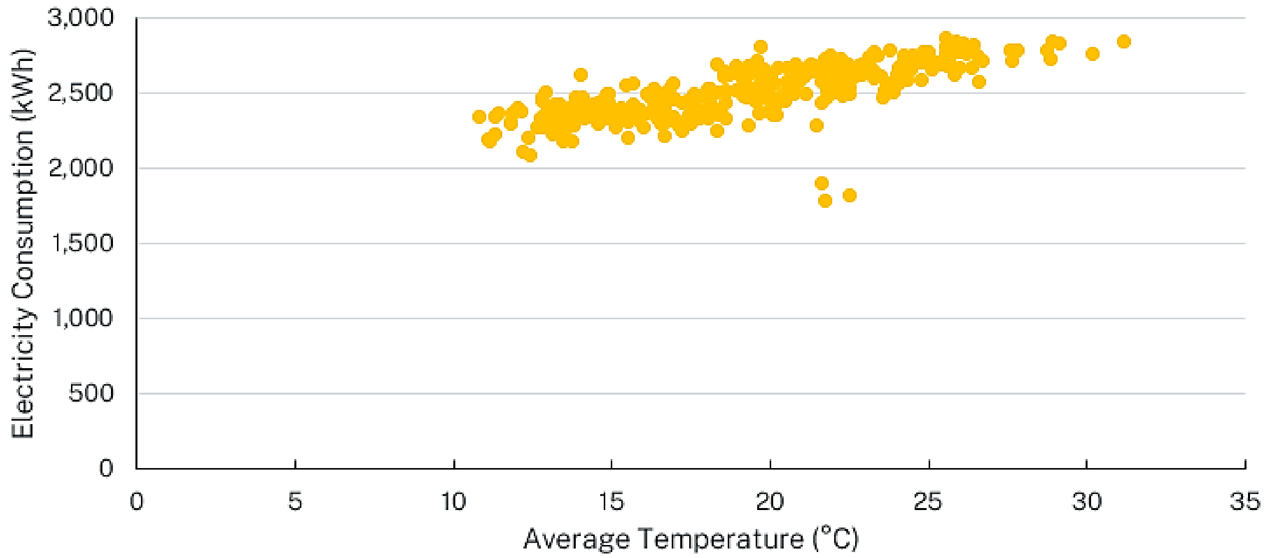
The estimated cost of implementing the EEMs was $26,500 plus GST (excluding any costs associated with M&V).

## Factors that explain variation in energy use

As shown in figure 3, electricity consumption varies depending on the weather. Weather data was readily available from the Bureau of Meteorology (BOM).

An analysis of the daily electricity data concluded that days of week had some impact on energy use which was generally lowest on a Sunday and highest on a Wednesday (the variation was very small).

**Figure 3** Daily electricity consumption versus average temperature. The 3 points below the general trend correspond to days the site is shut (Christmas day, Good Friday, Easter Sunday)




### ⏪ Checklist of activities and outcomes with notes where there are deficiencies

☑ Annual site energy use, and variation in site energy use in recent years.

*Variation in recent years is unknown, only 17 months of data available.*

*It would be better to have 24 months or more of data.*

☑ The impacted equipment.

☑ How the EEM saves energy.

☑ What the likely savings are, in energy units and as a percentage of total site energy use.

☑ What data the energy service provider has used when estimating savings and where the data has been sourced.

☑ Understanding the loads that are supplied by any existing sub-meters that will be used for M&V and having documentation on this such as single line diagrams.

☑ Where sub meters exist, how data is collected from the submeters and the reliability of meters and data collection from the meters.

☑ What factors are likely to determine how energy use of the impacted equipment varies and whether or not data is available on these factors.

### Activities by M&V practitioner

- ☑ Engaged with the energy service provider.
- ☑ Visited the site.
- ☑ Inspected the equipment that it is proposed to upgrade and have (ideally) taken photos of the equipment in its original position.
- ☑ Inspected meters including meters for potential independent variables. Recorded meter numbers and calibration details.
- ☑ Understood what data is available and from where it is sourced, how it is stored and who is responsible for data collection.
- ☑ Have an appreciation for site operations and how they may impact daily energy use.

# Step 3 Determine the M&V approach


This step involved the M&V practitioner deciding which International Performance Measurement and Verification Protocol® (IPMVP) options to use and where to draw the M&V measurement boundary.

The IPMVP options are:

- Option A: retrofit isolation, key parameter measurement
- Option B: retrofit isolation, all parameter measurement
- Option C: whole facility
- Option D: calibrated simulation.

You can find out more about each of the IPMVP options in the M&V Guide, module 1 and module 2.

In this example, the expected savings were estimated to be above 10% of annual energy use, which is relatively high. Additionally, as the VO unit upgrades applied to the whole site, electricity savings could only be determined by using IPMVP Option C. This meant the site needed to be carefully monitored for any changes to the selected static factors.

## Data availability

Available data included:

- daily weather data: from the nearest BOM weather station
- daily site operating hours:
  - Monday to Friday: 7 am to 10 pm
  - Saturday and Sunday: 8 am to 10 pm
- day of week: each weekday could potentially be used as a binary variable
- whether the site is closed for a public holiday: the site is closed for Christmas Day, Good Friday, Easter Sunday only
- supermarket floor area: 610 $m^2$.

## M&V Budget

The M&V budget was set as follows:

- $3,000 to develop the M&V plan
- $2,000 for the M&V report identifying savings
- $1,000 annually after the first year, for ongoing yearly verification the savings.

**Considered in the M&V approach with notes where it was not covered**

☑ Required accuracy with which savings are to be determined.

☑ Time available to develop a baseline.

☑ Available data and its quality.

☑ Available M&V budget.

# Step 4 M&V meeting to finalise responsibilities and budget

This step involves bringing all parties together to finalise responsibilities and budget including the M&V practitioner, energy services provider and the energy user.

In this example, the following items were discussed:

- Why electricity consumption was lower in the first 5 months of 2019 compared to the same period in 2018. It was explained that it was not possible to identify what had caused this change.
- The inclusion of the first 5 months of 2019 in the baseline period (12 months in total) to enable an accurate and more representative determination of savings from the EEMs.

During this meeting, it was agreed that:

- the M&V budget for the plan and report was to be accepted
- the M&V practitioner would visit the site first to support preparation of the M&V plan
- a 2 week period would be needed to install and commission the VO unit and VSDs
- reporting would begin after the equipment was commissioned. The reporting period length and approach to data collection will be identical to the baseline period
- there were no upcoming planned changes to the site that may impact on energy use
- the M&V practitioner check for any site changes every 3 months during the reporting period
- the M&V plan would be sent to supermarket management once finalised.

**Checklist of activities and outcomes with notes where there are deficiencies**

☑ Confirm what data is needed to be collected.

☑ Agree what sub-metering (if any) needs to be installed or upgraded.

*Sub-metering didn't need to be installed*

☑ Agree who will monitor changes at the site that may impact on M&V.

☑ Discuss when the M&V plan will be completed.

☑ Confirm who will be granted site access permissions to verify the correct EEM installation.

☑ Discuss how often will savings reports be provided and for how long.

☑ Agree to what the M&V budget is.

☐ Discuss how changes in staff will be managed over the life of the project (which could stretch into several years) to ensure all parties remain adequately informed.

*Final point was not discussed in the meeting.*

# Step 5 Data collection


This step involves the adequate coordination between the energy user, energy service provider and the M&V practitioner to ensure the appropriate communication and collection of data.

## Energy data

Electricity interval data was collected then summarised into daily data.

## Potential independent variables

Potential independent variables were:

- temperature and relative humidity, which was determined using weather data was collected from the nearest Bureau of Meteorology (BOM) weather station
- the day of week as a binary variable
- whether or not it is a day the site was closed as a binary variable (Christmas day, Good Friday, Easter Sunday).

A sample of the potential independent variables is shown in table 1.

**Table 1** Sample of the potential independent variables

| Date | kWh | Average temperature (°C) | Mon | Tue | Wed | Thu | Fri | Sat | Sun | Site closed |
|---|---|---|---|---|---|---|---|---|---|---|
| 1/07/2019 | 2145.2 | 12.85 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2/07/2019 | 2111.4 | 13.8 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3/07/2019 | 2155.4 | 13.7 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| 4/07/2019 | 2228.4 | 13.75 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| 5/07/2019 | 2256.8 | 16.1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

| Date | kWh | Average temperature (°C) | Mon | Tue | Wed | Thu | Fri | Sat | Sun | Site closed |
|---|---|---|---|---|---|---|---|---|---|---|
| 6/07/2019 | 2200.1 | 14.8 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| 7/07/2019 | 2190.2 | 15.4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 8/07/2019 | 2265.8 | 16.2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

## Static factors

The static factors identified were:

- store operating hours: Monday to Friday, 7 am to 10 pm
- store operating hours: Saturday and Sunday, 8 am to 10 pm
- site floor area: 610 $m^2$
- number of
  - internal 40 W (LED) troffer lights: 150
  - external 100 W (LED) flood lights: 6
  - toilet exhaust fans: 2
  - packaged air conditioning units: 3
  - cool room evaporator units: 2
  - freezer room evaporator units: 2
  - refrigeration compressors in total: 10
  - air-cooled condensers: 6
  - freezer cabinets: 10
  - refrigerated cabinets: 12
- refrigeration equipment run times: 24 hours a day, 7 days a week, 365 days a year
- HVAC operating hours:
  - Monday to Saturday, 5:30 am to 9:30 pm
  - Sunday, 6 am to 9 pm

## Interactive effects

It was determined that there were no interactive effects since changes to site electricity consumption have no impact on the amount of gas consumed by the supermarket.

All the interval data collected for the supermarket was considered to have zero error due to the quality of data source.

**Checklist of activities and outcomes with notes where there are deficiencies**

- ☑ Measurement instruments are in place to collect data.
- ☑ Understand the instrument accuracy and calibration and confirm they are fit for purpose.
- ☑ Confirm measurement instruments perform reliably.
- ☑ Can track the reliability of data collection and a process to take corrective action if there are failures.
- ☑ Data is collected.
- ☑ Data is stored in a place that is readily accessible to the M&V practitioner.

**Checklist of data collected with notes as needed on data collection actions**

- ☑ Energy data.
- ☑ Data on potential independent variables.
- ☑ Data on static factors.

# Step 6 Data analysis


To build a representative energy model, the M&V practitioner undertakes a data analysis for the M&V process. In this example, the M&V practitioner built an acceptable regression model using the daily interval data with multiple independent variables.

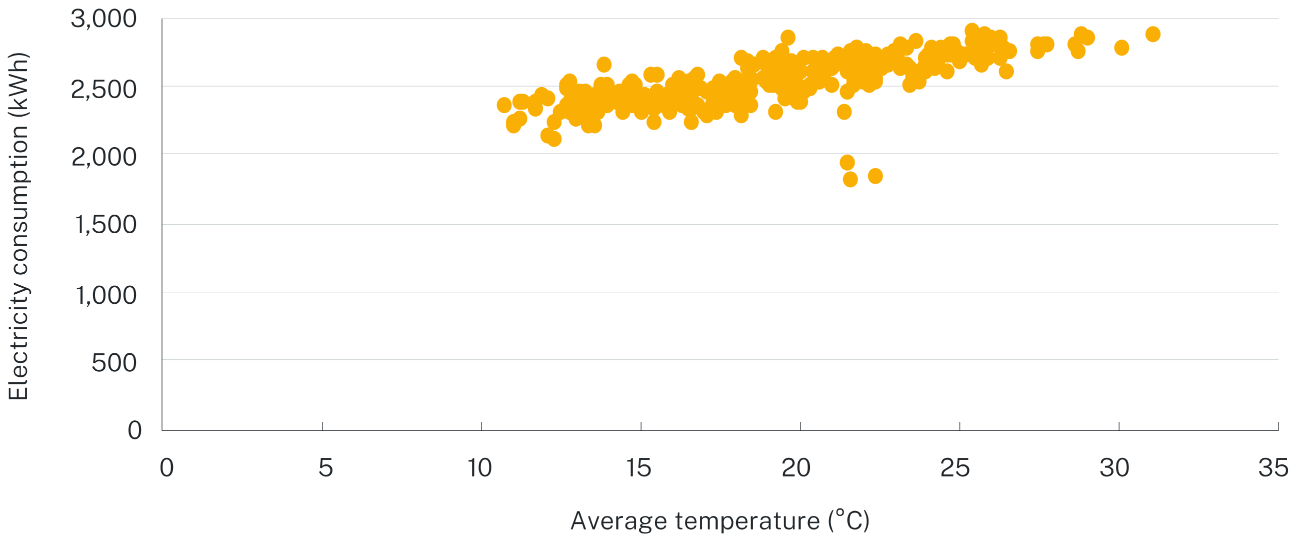
The 12 months with the lowest total energy use was chosen as the baseline which was the 12 month period up to the end of May 2019. This was because of the unexplained lower energy use in the first 5 months of 2019, compared to the same period in 2018. This reduction could not be considered as savings ascribed to the EEMs as neither upgrade had been installed. This aligned with the IPMVP principle of 'being conservative' when determining the savings.

**Note: by 'being conservative', there was a small drop in 'accuracy' (another IPMVP principle). This is illustrated in Appendix B of this case study.**

Data analysis steps taken were:

- Electricity interval data at daily intervals was plotted against average temperature to determine if either the average temperature, degree days (or a combination of degree days) could be taken as an independent variable. With no inflection point, average temperature was identified as a suitable independent variable as shown in figure 3.

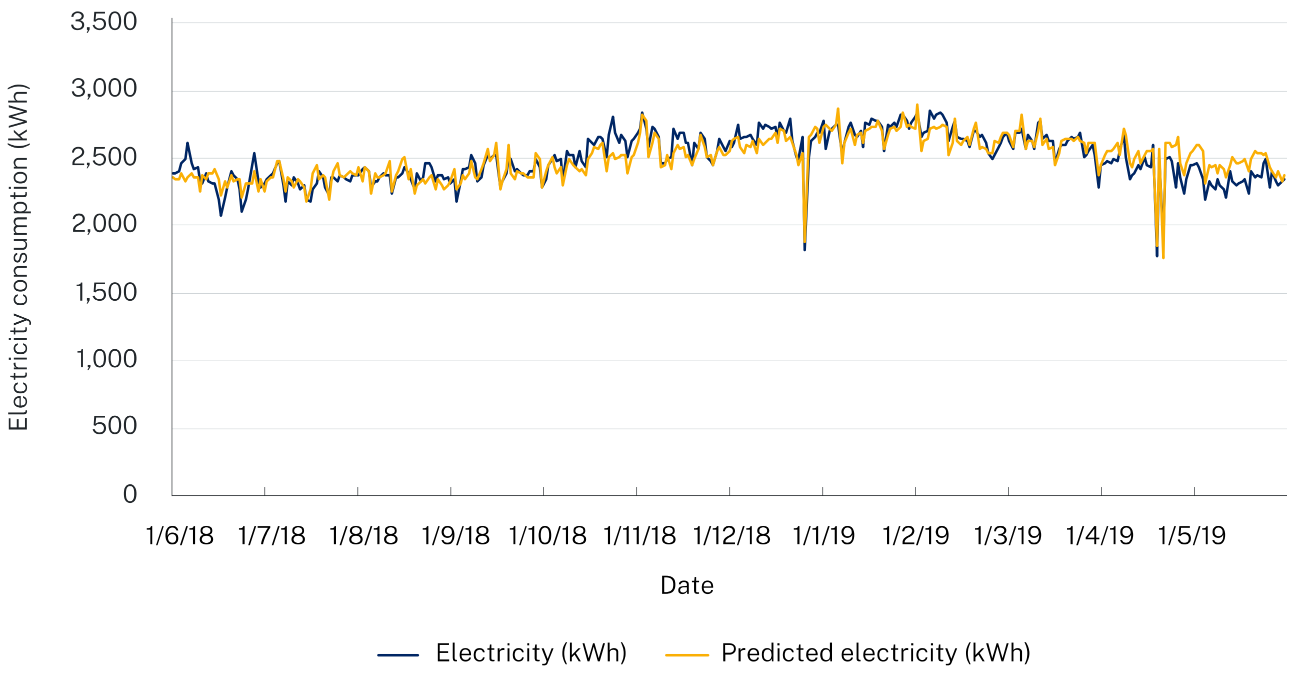
**Figure 3** Daily electricity consumption versus average temperature. The 3 points below the general trend correspond to days the site is shut (Christmas day, Good Friday, Easter Sunday)




- A baseline energy model using regression analysis was created using the following independent variables:
  - average temperature
  - whether the weekday is Sunday as a binary indicator
  - whether the site is shut as a binary indicator.

The actual and predicted baseline electricity consumption are shown in figure 4.

**Figure 4** Baseline actual and predicted electricity consumption




The baseline energy model was checked against the IPMVP statistical recommendations:

- t-statistic > |2|
- $CV_{RMSE} < 0.2$
- $R^2 > 0.75$.

The model statistical test results are shown below in tables 2 and 3. The range of independent variables in the model, and regression variable, is shown in table 3.

The baseline model relative precision was 5.5% at the 90% confidence level.

Note: Appendix B of this case study includes a residuals plot of the baseline model.

**Table 2** Baseline model statistical test results

| Parameter | Value | IPMVP recommendation | Acceptable? |
|---|---|---|---|
| Observations per independent variable | 121.7 | ≥ 6 | Yes |
| Expected values error | 0.000% | < 0.005% | Yes |
| Adjusted $R^2$ | 0.78 | > 0.75 | Yes |
| $CV_{RMSE}$ | 0.033 | < 0.2 | Yes |

**Table 3** Baseline model coefficients, t-statistics and range of independent variables

| Parameter | Intercept | Average temperature | Sunday | Site closed |
|---|---|---|---|---|
| Coefficient | 1919.7 | 31.237 | -86.559 | -744.53 |
| t-statistic | 99 | 32 | -6.9 | -15 |
| t-statistic acceptable? (> \|2\|) | N/A | Yes | Yes | Yes |
| Minimum value | N/A | 10.85 | 0 | 0 |
| Maximum value | N/A | 31.2 | 1 | 1 |

**Checklist of activities and outcomes with notes where there are deficiencies**

☑ Process raw data into consistent time intervals. For example, electricity interval data at 30 minute intervals is converted to daily data to align with weather data that is only available daily.

☑ Identify any missing data.

☑ Deal with missing data.

☑ Identify potential independent variables that could be used in the regression model.

☑ Develop the regression model(s).

☑ Evaluate the acceptability of the regression model(s).

☑ Identify the range of the model.

☐ Test (optional, but strongly recommended) the model against other periods to detect any unidentified factors that may cause significant variation in energy use between years. If this is the case, consider narrowing the measurement boundary.

*This was not done as there was only limited data available.*

# Step 7 Is the energy model acceptable?

This step is decided by the M&V practitioner based on the previous data analysis step. The baseline energy model as summarised in tables 2 and 3 is deemed acceptable because:

- it met the IPMVP statistical requirements
- it had a standard error of 0.2%.

The IPMVP requires that savings be at least twice the savings' standard error. Since the expected energy savings were estimated to be 14%, it is highly likely that the actual energy savings would be well over twice the standard error (0.4%).

**Checklist of activities and outcomes with notes where there are deficiencies**

☑ The model satisfies certain statistical test ($R^2 > 0.75$, t-statistics > 2, $CV_{RMSE} < 0.2$, predicted values error is < 0.005%).

☑ The modelling error is sufficiently low that it will be possible to determine the savings with an acceptable level of uncertainty.

# Step 8 Complete the M&V plan


The M&V Plan is the document prepared by the M&V practitioner that details the methods, procedures, analyses, and reporting that will be conducted throughout the measurement periods to determine, verify, and report the eligible fuels savings.

This document was prepared while ensuring that the requirements of EVO 10000 – 1:2022, IPMVP Core Concepts 2022, chapter 13, are met. The M&V plan is presented in Appendix C.

# Step 9 Present the M&V plan and agree on reporting responsibilities

This step involves presenting the M&V plan and agreeing on reporting responsibilities. In this example, the M&V plan was presented to the energy services provider and the supermarket management. A discussion followed which covered:

- the measurement boundary and IPMVP option selection
- the creation of the baseline energy model using regression analysis
- the expected uncertainty of savings determination
- static factors and independent variables
- agreement on the format and contents of M&V savings reports.

Regarding the reporting period, it was agreed:

- the M&V practitioner would continue to collect data directly from the energy retailer and BOM
- the supermarket management would monitor changes in the static factors and advise the M&V practitioner of any expected or actual energy changes
- an M&V report would be presented showing the savings over the 12-month period following the upgrade.

It was recommended the M&V plan be assessed by a third party expert for quality assurance (QA) before being approved. An M&V professional, with significant M&V expertise, would review the M&V plan, including the calculations, and ensure it adhered to the principles of the IPMVP. This would provide greater certainty of the savings determined through M&V. It was agreed a QA assessment would be worthwhile and a quote was received for $1,000.

**Checklist of activities and outcomes with notes where there are deficiencies**

☑ Present the plan.

☑ Agree on responsibilities moving forward.

☑ Agree on the timeline for M&V plan approval and quality assurance.

# Step 10 Approve the M&V plan (including quality assurance)


This step involves issuing an approval of the M&V plan presented and, in this example, included an independent quality assurance (QA) assessment. This assessment confirmed that the plan was conservative on its baseline period. If it had not been, it may have been rejected.

However, the QA assessment also found that the estimates for the EEMs' expected savings were not realistic. This was because, although VO units are effective in reducing energy consumption in equipment that directly consumes alternating current (AC) from the grid, the VSD installation on the refrigeration equipment meant that the refrigeration motors no longer directly consume AC electricity from the grid. The VSDs would act as inverters by first rectifying the main AC electricity supply to direct current (DC) then inverting it to provide AC power to the motors. The VSDs then change the speed of the AC motors by varying the frequency of supply to the motors. Therefore, once the VSDs were installed, there would be no savings from the refrigeration equipment as a result of the VO unit. Since the energy services provider had not taken this into account when estimating the overall savings, they were over-estimated.

This was accepted by the supermarket management. While concerned that the savings may not be as high as initially expected, they agreed the project would still proceed. The M&V plan was approved and signed.

**Checklist of activities and outcomes with notes where there are deficiencies**

- ☑ Quality assurance of the M&V plan.
- ☑ Approve or adjust the M&V plan.

# Step 11 Verify correct EEM operation


This step follows the implementation of the EEM and is performed by the M&V practitioner.

The EEMs were installed and commissioned over a 2 week period. Immediately following the installation of the VO unit and VSDs, the M&V practitioner visited the site to inspect the installation.

After a month, the site interval data was analysed to determine if the savings matched what was expected.

The avoided energy use percentage of the baseline consumption over the first month following the installation was just under 10%. This was lower than expected (14%).

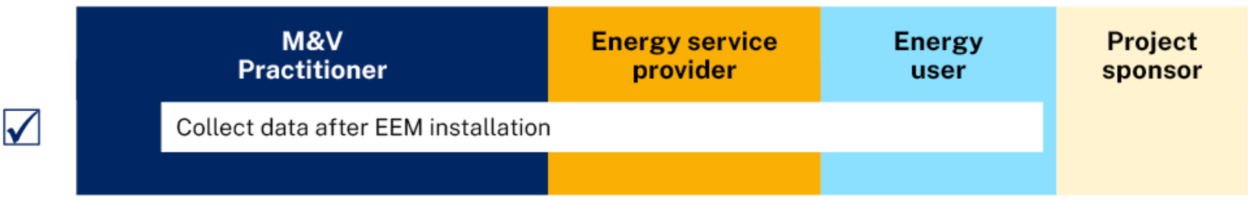
Subsequent inquiries revealed that the EEMs were operating as designed with voltage measurements showing that the VO unit was reducing the voltage levels. This confirmed that the EEMs were operating as intended but that savings over 12 months could be lower than expected.

**Checklist of activities and outcomes with notes where there are deficiencies**

- ☑ Inspect the new equipment on-site and, if needed, take spot measurements to verify correct operation.
- ☑ Analyse preliminary data coming through, to see if energy use is as expected.
- ☐ Address any deficiencies (for example, by advising the energy services provider).

  *Not necessary.*

## Step 12 Data collection after the EEM installation




Following the EEM implementation, energy consumption data was collected for 12 months. The M&V practitioner contacted the supermarket management a month into the data collection to provide an update on the savings. The supermarket management was happy with the new equipment operation and confirmed no changes to site operations or to the designated static factors.

The M&V practitioner continued to engage with the supermarket management every 3 months to discuss any changes at the site which may cause energy use to increase or decrease. There were no such changes to the static factors.

During the second check (6 months after installing the EEMs), the store manager advised that he was moving to a different store within the organisation. The new store manager was briefed on the project, and it was agreed that the new store manager would continue monitoring the site and collaborating with all stakeholders involved in the project.

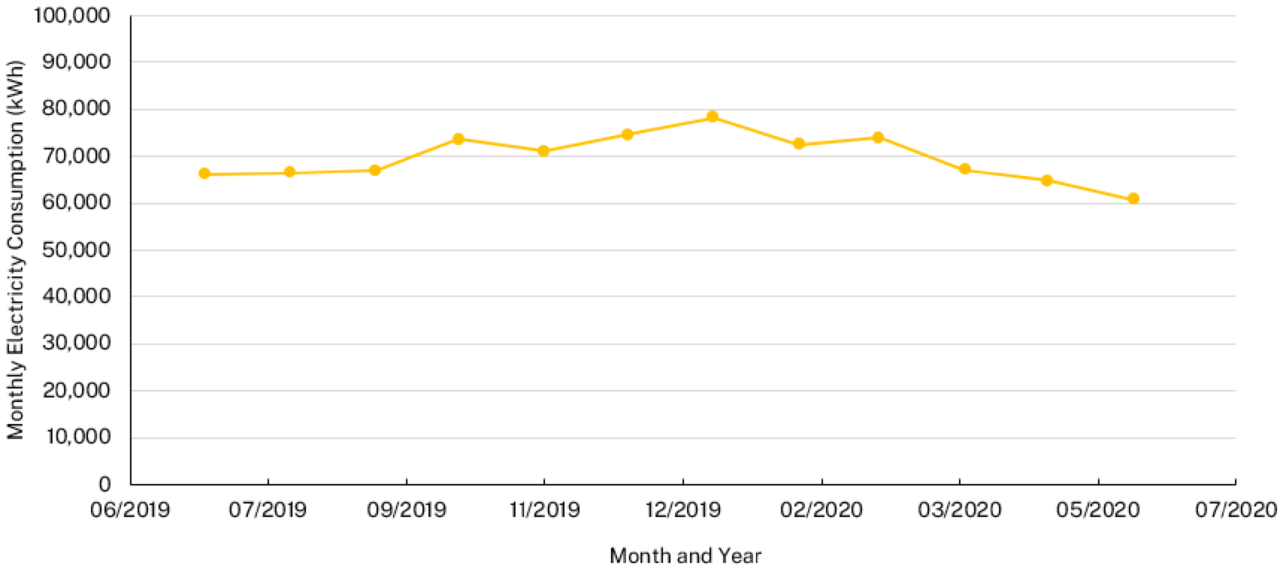
# Step 13 Savings determination


To determine energy savings in way that enables the creation of ESCs, a reporting energy model will be established using regression analysis.

## Reporting period energy use

Data was collected for 12 months following the upgrade, from 1 July 2019 to 30 June 2020. Figure 5 shows monthly electricity consumption over this period. As with the baseline period, energy use is highest in summer and lowest in winter.

**Figure 4** Monthly electricity consumption in the 12 months following the upgrade




**COVID-19 impacts:** in Australia, the COVID-19 pandemic impacts started from mid-March 2020, however the supermarket management reported there were no changes in operating hours nor the supermarket floor area due to COVID-19. This is because the supermarket was considered as performing essential services. The energy use profile did not change significantly from the expected normal operation from mid-March 2020. Therefore, COVID-19 did not appear to have any impacts on electricity use.

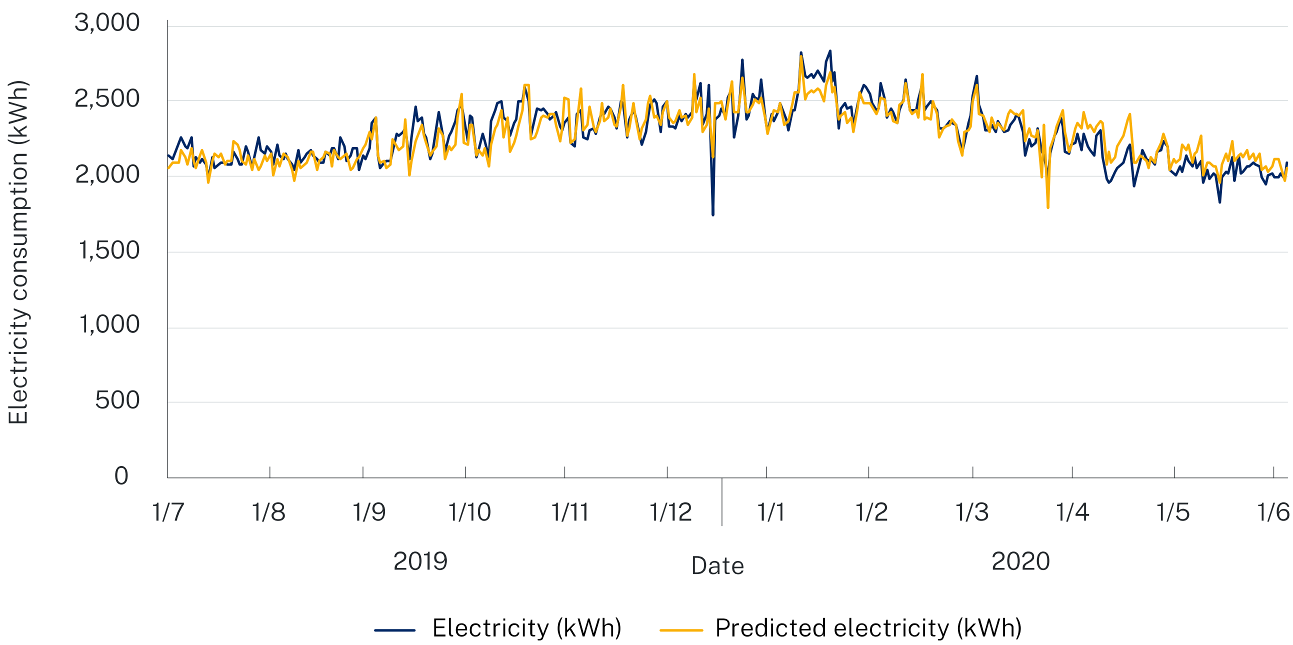
Additionally, there were no changes to any of the other static factors.

The M&V practitioner consulted the IPMVP Application Guide to Non-Routine Events and Adjustments and determined that there was no need to undertake a non-routine adjustment.

## Reporting period regression model

Using the same set of independent variables chosen for the baseline period energy model, an energy model was built using regression analysis for the reporting period, as shown in figure 6.

**Figure 5** Daily actual and predicted electricity consumption in the reporting period




## Acceptability of the reporting period energy model

Tables 4 and 5 show that this model satisfies the IPMVP statistical requirements for regression analysis. This means the reporting period energy model is ‘acceptable’.

**Table 4** Reporting (operating) model statistical test results

| Parameter | Value | IPMVP recommendation | Acceptable? |
|---|---|---|---|
| Observations per independent variable | 122 | > 6 | Yes |
| Expected values error | 0.000% | < 0.005% | Yes |
| Adjusted $R^2$ | 0.79 | > 0.75 | Yes |
| $CV_{RMSE}$ | 0.038 | < 0.2 | Yes |

The relative precision of the reporting period model was 6.2% at the 90% confidence level.

**Table 5** Reporting model coefficients, t-statistics, and range of independent variables.

| Parameter | Intercept | Average temperature (°C) | Sunday | Site closed |
|---|---|---|---|---|
| Coefficient | 1560.6 | 38.444 | -71.474 | -365.91 |
| t-statistic | 74 | 36 | -5.6 | -7.3 |
| t-statistic acceptable? (> \|2\|) | N/A | Yes | Yes | Yes |
| Minimum value | N/A | 11.55 | 0 | 0 |
| Maximum value | N/A | 32.2 | 1 | 1 |

## Basis for savings determination – normalised energy savings.

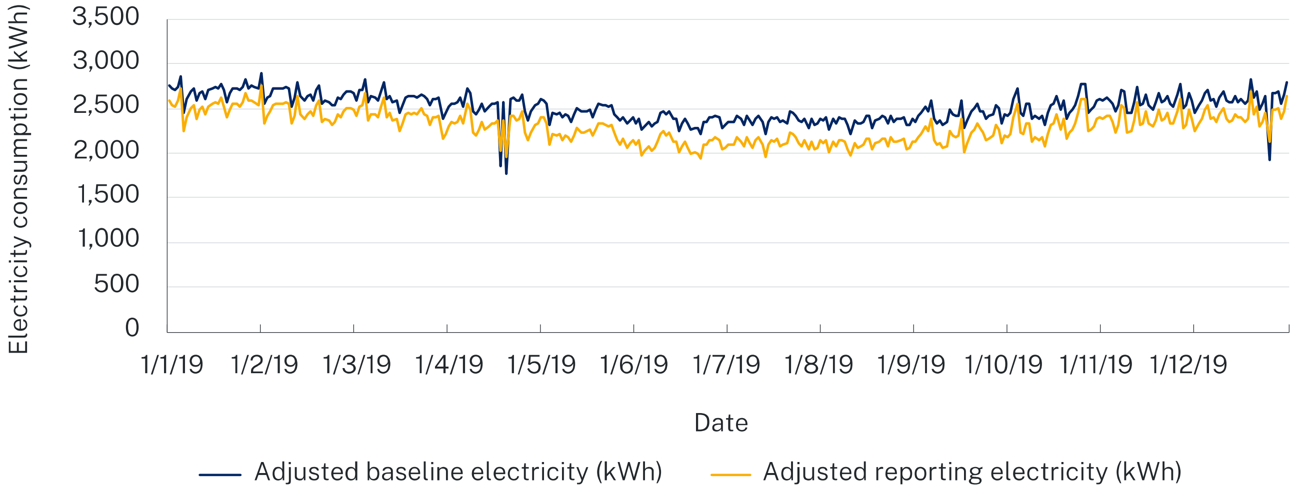
To determine the normalised savings, a normal year must be selected. The normal year is one in which the mean, range and variation of independent variables is likely to represent the operation of the site over the lifetime of the energy efficiency measures.

In this example, the M&V practitioner selected the calendar year 2019 as the normal year. This was identified as being reflective of the expected typical operation of the site in the future, with the supermarket largely unimpacted by COVID-19.

## Determination of normalised savings.

Based on the values of the independent variables for each day of the normal year, the expected baseline and reporting energy use values were calculated using their respective energy models as shown in figure 7.

**Figure 6** Baseline and reporting energy use in the normal year (based on the developed regression models)




The range of independent variables in the normal year, baseline period and reporting period are very similar. Moreover, all observations in the normal year are within plus or minus 5% of the range of both the baseline and operating period models. Savings were determined to be 8.5% of the (adjusted) baseline energy use as shown in table 6.

**Table 6** Savings determination

| Parameter | Value (kWh) |
|---|---|
| Total adjusted baseline energy | 916,702 |
| Total adjusted reporting energy | 838,921 |
| Total normalised savings | 77,782 |
| Savings as a percentage of the adjusted baseline | 8.5% |
| Error in savings determination at the 90% confidence level | 7,248 |
| Relative precision* | 9.3% |

* Relative precision is the error in savings at the 90% confidence level as a percentage of savings. Autocorrelation has been considered when determining the relative precision.

The uncertainty in the savings determination is based on the errors associated with the measurement of energy use and from the modelling. Sources of error were:

- baseline model uncertainty (at 90% confidence level), taking into account autocorrelation: 293 kWh

- reporting period model uncertainty (at 90% confidence level), taking into account autocorrelation: 241 kWh

There is no uncertainty associated with metering since the utility electricity meter was used (IPMVP Option C). The standard uncertainties were combined in quadrature (square root of the sum of the squares) and multiplied by the square root of the number of observations (365) to give an overall uncertainty of savings across the year.

Savings uncertainty (at the 90% confidence level) = $\frac{\sqrt{(293^2 + 241^2)}.\sqrt{365}}{77,782}$ = 7,248 kWh.

The IPMVP requires that annual savings be more than twice the standard error. In this example, savings were more than twice the standard error.

**Checklist of activities and outcomes with notes where there are deficiencies**

☑ Identify the period over which savings are to be reported.

☑ Determine the basis by which savings will be calculated.

☐ Complete non-routine adjustments to account for unexpected changes at the site, unrelated to the EEM, which may cause energy use to increase or decrease.

*No non-routine adjustments were needed.*

☑ Identify those intervals where savings cannot be determined.

☑ Calculate the savings.

☑ Determine the uncertainty in the savings.

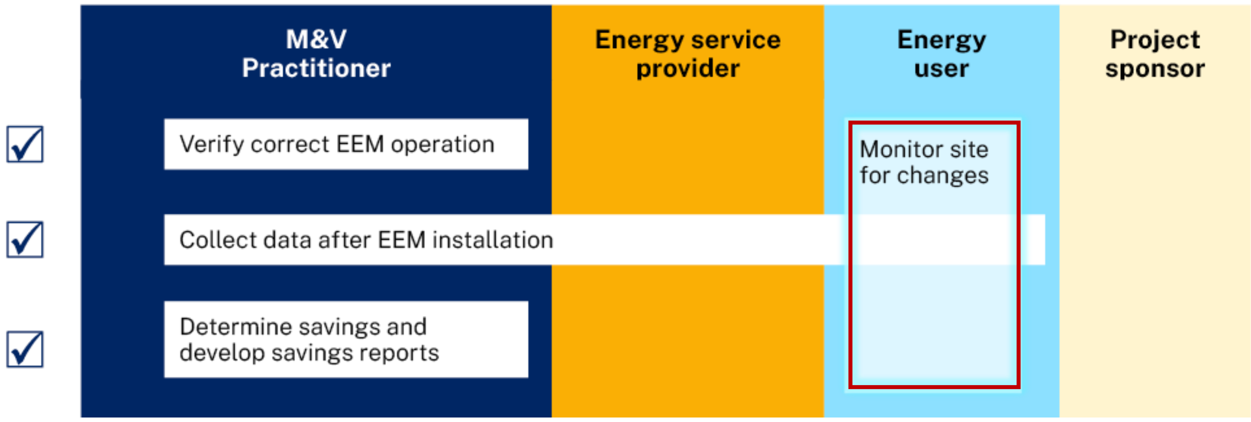
☑ Check that the savings are more than twice their standard uncertainty.

☑ State the savings along with the uncertainty at the desired confidence level.

# Step 14 Develop savings reports

The M&V Report is a document prepared by the M&V practitioner after the implementation of the EEM to detail and communicate the findings of the M&V process using the procedure outlined in the M&V plan. It is prepared in a way that is in adherence with the reporting requirements described in chapter 13 of IPMVP Core Concepts 2022. The first savings report is included in Appendix D.

# Step 15 Monitor site for changes




This step involves the energy user monitoring changes to site that may impact energy consumption.

The supermarket management agreed to continue the ongoing monitoring, verification and reporting of energy savings. It was agreed tracking the supermarket electricity consumption quarterly would enable the ongoing verification of the expected savings. The annual cost of conducting ongoing monitoring was $1,000. This cost was based on desktop monitoring only and excluded site visits.

It was also agreed that in the event of any deviation of more than 2%[1] from the expected site electricity use, the M&V practitioner contact the supermarket management to understand what site changes might have led to that change.

**Note: if energy use is higher than expected, this represents a loss of savings and if energy use is lower than expected this represents increased savings.**

The reason for quarterly monitoring is to identify if there may have been changes at the site that could cause savings to decrease or increase and to also monitor whether the EEMs have continued to perform as expected.

If there are no site changes (changes to static factors) but quarterly energy use deviated by more than 2% of expected energy use, then the M&V practitioner could request an inspection of the VO unit and the VSDs performance to determine if the EEMs were still operating as intended.

The M&V practitioner also agreed to prepare annual savings reports including a graph of cumulative savings.

[1] With savings of 8.4%, a 2% variation in expected energy use is roughly ¼ of the savings.

# Step 16 Debrief and do better M&V

| | M&V Practitioner | Energy service provider | Energy user | Project sponsor |
|---|---|---|---|---|
| ☑ | Debrief and apply the learnings to future energy efficiency projects | | | |

This step involves holding a meeting that includes all parties.

A short debrief meeting was held over the phone one month after the submission of the first savings report between the M&V practitioner, the energy services provider, and the supermarket management. The following discussions took place:

- The amount of savings was less than initially expected. The M&V practitioner advised that the equipment appeared to be operating as intended, and that the energy services provider had likely miscalculated the savings.
  - The energy services provider agreed to review their savings calculation methodology (for future projects) and acknowledged they had not considered the interaction between the voltage optimisation unit and the VSDs as was predicted by the independent QA reviewer.
- The M&V process was seen as beneficial by all parties. While the savings weren't as expected, the supermarket management was happy with the level of M&V undertaken and with the advice provided by the independent expert on the M&V plan.
- The supermarket management concluded that the main benefit of the M&V was that it helped establish the savings in a way that was trustworthy and could inform the rollout of similar upgrades at other branches of the supermarket chain. Apart from the financial incentives from the scheme certificates, the clear and trustworthy determination of savings was seen as the greatest benefit of M&V.
- As a lesson learned, the supermarket management decided to seek performance guarantees from any future energy service providers and to continue to use third-party QA reviews to verify M&V processes.

**Checklist of activities and outcomes with notes where there are deficiencies**

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

☑ What benefits did M&V provide?

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

For more information on the Energy Security Safeguard

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