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

Measurement and verification demonstration project

Food manufacturer: Dryer burner replacement

August 2024

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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 food manufacturing facility using the *Guide to measurement and verification of energy efficiency projects in Australia* (the 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 food manufacturing facility 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

The manufacturing of food products is an energy intensive process which may include machinery that use electricity and gas. This food manufacturing facility described in this demonstration project produces a range of products including dehydrated foods.

This demonstration project shows how a food manufacturer implemented an effective M&V process to capture the full benefit of savings that resulted from energy efficiency initiatives across the facility.

The manufacturing site featured in this example uses both electricity and gas, where gas is mainly used as follows:

1. to generate steam
2. in the hot water boilers
3. in a direct-fired dryer for dehydration purposes.

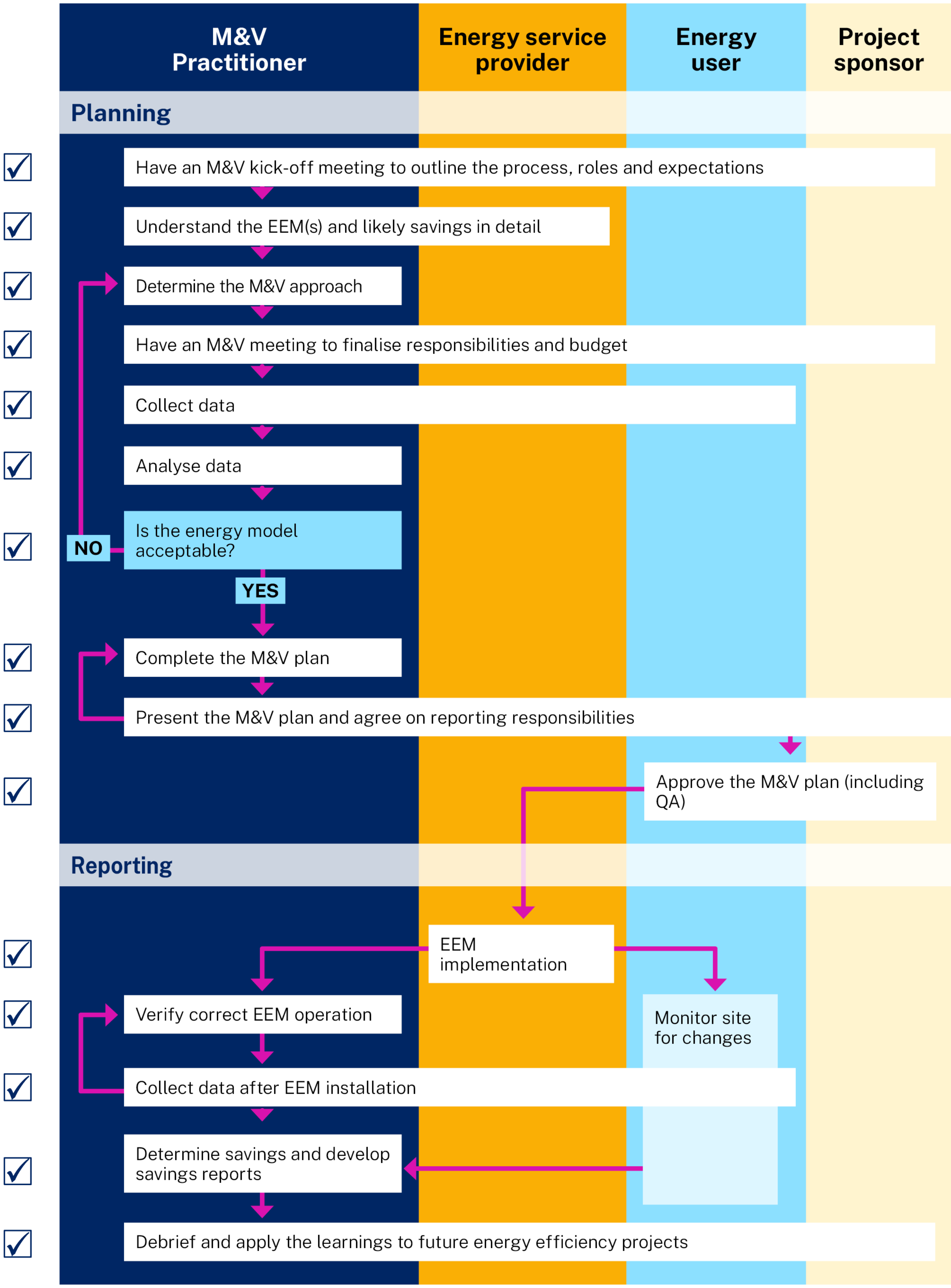
With the rising cost of gas and a desire to reduce emissions, several energy efficiency measures (EEMs), focusing on gas reduction, were implemented at the site. These included:

- replacing the gas dryer burners with more efficient burners

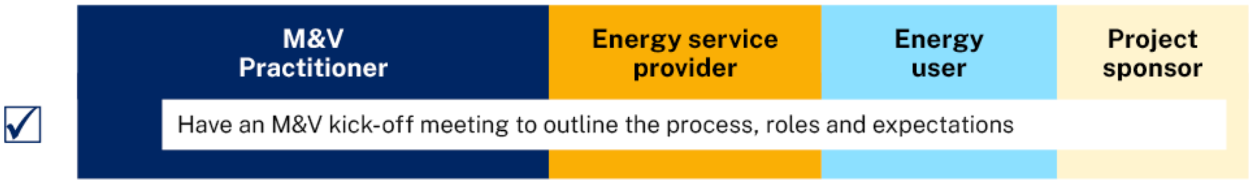
- fitting variable speed drives (VSDs) to the burner fans
- upgrading the dryer sensors and controls.

These upgrades were expected to save electricity and gas 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 food manufacturer (energy user) after they had decided to replace the burners on the gas dryer, install VSDs on their fans and upgrade the sensors and controls on the dryer.

The kick-off meeting involved several stakeholders including the:

- food manufacturer's production manager (the energy user)
- energy services provider
- M&V practitioner - Accredited Certificate Provider (ACP).

In some cases, the kick-off meeting would also include the external financier, however in this example, the upgrades were funded by the food manufacturer.

The energy services provider estimated the annual energy savings from these projects to be:

- 300 MWh of electricity (or 1% of site electricity use)
- 4,000 GJ of gas (or 3% of site gas use).

At an average electricity tariff of around $0.21/kWh and an average gas tariff of around $10.70/GJ, the annual energy bill savings would be $106,000. Assuming these annual saving declined at 1% per year over the 15 year expected life of the equipment, the energy bill savings would be around $1,480,000.

The energy services provider also recommended undertaking a M&V process to enable the creation of Energy Savings Certificates (ESCs) under the NSW Project Impact Assessment with M&V (PIAM&V) method.

One of the benefits of creating ESCs is that the proceeds from their sale can offset some of the upgrade costs. Using the savings estimates as a guide, the ESCs revenue over the life of the upgrade would be $190,000 (at an assumed ESC price of $30 per ESC) or approximately

$160,000 after deducting 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. Actual savings determined through M&V could be significantly different
- The ESC price may change and can be unpredictable
- ESC broker fees and registration fees would reduce the overall amount received by the manufacturer by around $5 per certificate.

The M&V practitioner also advised because the expected savings were small relative to the whole-of-site energy consumption, dedicated electricity and gas submeters should be installed on the electricity and gas supply to the dryer to enable savings to be determined accurately (see step 3 for further details).

It was also noted that the quality of the gas utility data was poor and by installing submeters, data would improve significantly. This would allow the identification of any additional efficiency opportunities.

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 estimated sub-metering costs were around $25,000.

The M&V practitioner encouraged the production manager to:

- facilitate the installation of metering, its connection into the existing supervisory control and data acquisition (SCADA) system and provision of data to the M&V practitioner
- monitor the site and alert the M&V practitioner of any changes to the way the dryer was used. This should include activities that would impact energy consumption such as changes to temperature settings or non-routine events such as unexpected shutdowns
- consult with the M&V practitioner before implementing any other planned changes to the dryer, so these could be accounted for when determining savings.

The production manager advised that, apart from the EEMs, they had no other planned changes that could impact on the energy use of the dryer burner system and that they would inform the M&V practitioner of other changes. He also agreed on ongoing monitoring to verify the continuity of savings and acknowledged its importance.

The M&V practitioner advised that, if metering was to be installed, data would need to be collected to establish a baseline that represented a complete cycle of the operating conditions which could be up to 12 months. It was therefore necessary to analyse the data for the first 60 days after installing the meter to determine how long the baseline measurement period should be.

The production manager's preference was to implement the upgrade to coincide with a scheduled plant shut down. The parties agreed to establish a baseline before this, noting that it might be necessary to install the new burners after the shutdown if it was not feasible to build an acceptable baseline energy model beforehand.

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 the estimated energy savings
- share any on-site energy use data collected with the M&V practitioner
- commence the energy efficiency upgrades only after the M&V practitioner had advised that a suitable energy baseline period had been developed
- notify the M&V practitioner once the upgrades had been implemented and commissioned.

The M&V practitioner enquired about the food manufacturer's expectations around the accuracy of savings determination. To be able to assess with some confidence the actual cost-benefit of the project, the production manager advised that the maximum acceptable uncertainty would be plus or minus 20% of savings.

The overall budget for the M&V activities, including providing annual M&V reports and annual verification of savings, was estimated to be between $60,000 to $80,000. It was noted that the variation was subject to the site inspection. The production manager accepted this initial estimate.

To wrap up the kick-off meeting a date was set where the M&V practitioner could conduct the site visit.

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 undertaken. 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.

Checklist of activities and outcomes with notes where there are deficiencies

- ☑ 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 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 as well as a visit to the site.

Site description

The 45-year-old production facility is in an industrial area of a regional NSW city. A SCADA system is used to control process and production parameters. However, there is no sub-metering of electricity or gas consumption on any individual equipment.

Site energy consumption

The energy services provider advised that the site's energy consumption in 2018 was around 26,000 MWh of electricity and 150,000 GJ of gas. Electricity consumption varied from month-to-month but had no discernible pattern. Gas usage was slightly higher in winter.

Equipment impacted by the EEMs

The equipment that would be impacted by the EEMs was the dryer, which is used in the food dehydration process. The dryer usually operates every week from Monday to Friday, with the occasional weekend use to manage any increase in orders. There are also times when the dryer does not operate on Mondays.

Energy use of the equipment subject to the EEMs

After conducting an energy audit, the energy services provider estimated that the dryer used 800 MWh of electricity and 25,000 GJ of gas annually. There was no metered data to substantiate these estimates.

How the EEMs save energy

The role of the dryer in the production process is to remove moisture from incoming 'wet' food, resulting in a final dehydrated product. Food is dried in a batch process across several rooms by one dryer. The burners heat the air coming into the dryer. This hot air then dehydrates the wet food. Moisture from the food is transferred to the hot air and vented to the outside.

The dryer currently has 4 x 1,170 kW burners, with a total capacity of 4,680 kW. The burners are staged depending on the demand for heat. Before the EEMs were implemented, the burners used were non-modulating, high/low fire burners. Air was supplied through constant volume fans.

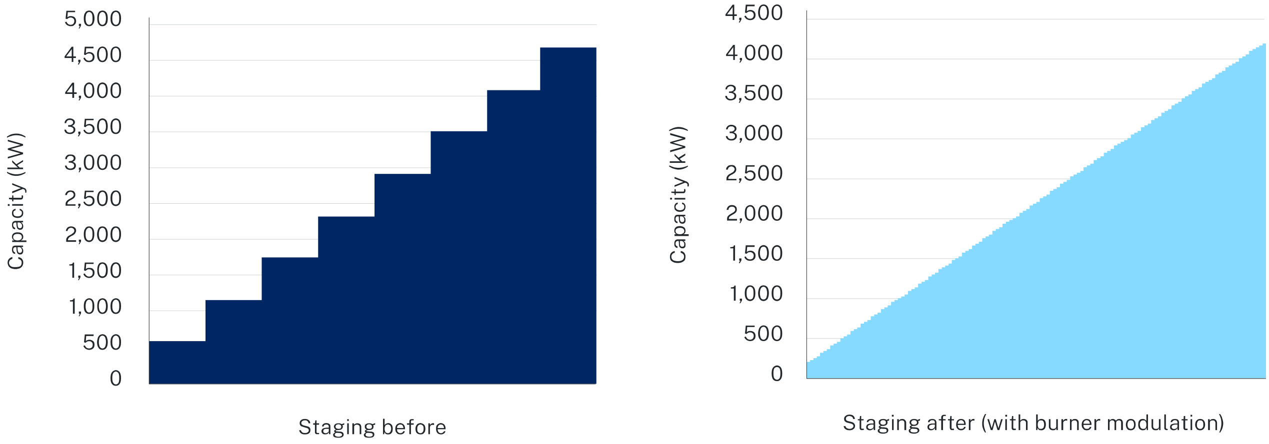
The proposed EEMs were to install:

- 1 x 1,600 kW burner, 2 x 1,000 kW burners and 1 x 600 kW burner, with a total capacity of 4,200 kW. These burners would be capable of modulating down to 30% load
- VSDs on the burner fans and sensors to enable more efficient combustion by reducing the amount of excess air when burners were modulated.

This upgrade enables much finer staging of the amount of heat supplied to the dryer, as shown in Figure 2, with smoother burner staging possible with the burners modulating down to 30%.

Note: the previous burners were oversized. A slight reduction in total capacity does not represent a reduction in the useful service delivered by the burners.

Figure 2 Burner upgrade enables fine burner modulation



By being able to better regulate the amount of heat and air meant that:

- more even drying of products could be achieved
- stop/start burner losses could be minimised
- combustion efficiency would be improved by reducing the amount of excess air in part load conditions.

Expected energy savings

The energy services provider estimated the expected annual savings to be 300 MWh of electricity and 4,000 GJ of gas.

Expected costs of implementing the EEMs

The estimated cost of implementing the proposed EEMs was $510,000 plus GST (excluding any costs associated with M&V).

Factors that explain variation in site energy use

It was expected there would be some variation in the site's electricity and gas use. An acceptable regression model could explain what these variations might be. To determine if an acceptable whole-of-site regression model was possible, data analysis was undertaken by the M&V practitioner.

The analysis determined that there was a correlation between energy use and weight of the product. However, the expected energy savings were small. This meant that using whole-of-site data as the basis for determining the savings achieved from the EEMs would not meet accuracy requirements of plus or minus 20%. Therefore, it was not possible to establish an acceptable whole-of-site regression model.

⏪ 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 14 months of data available.

  It would be better to have 24 months of data available.
- ☑ 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.

No submeters exist

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

No submeters exist

- ☑ 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 be upgraded 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.

No submeters exist

- ☑ Understand what data is available and where it has been sourced, how it is stored and who is responsible for data collection.
- ☑ Have an appreciation for site operations and how it may impact daily energy use.

Step 3 Determine the M&V approach

This step involves the M&V Practitioner deciding which International Performance Measurement Verification Protocol® (IPMVP) option to use and where to draw the M&V boundary.

The IPMVP options considered were:

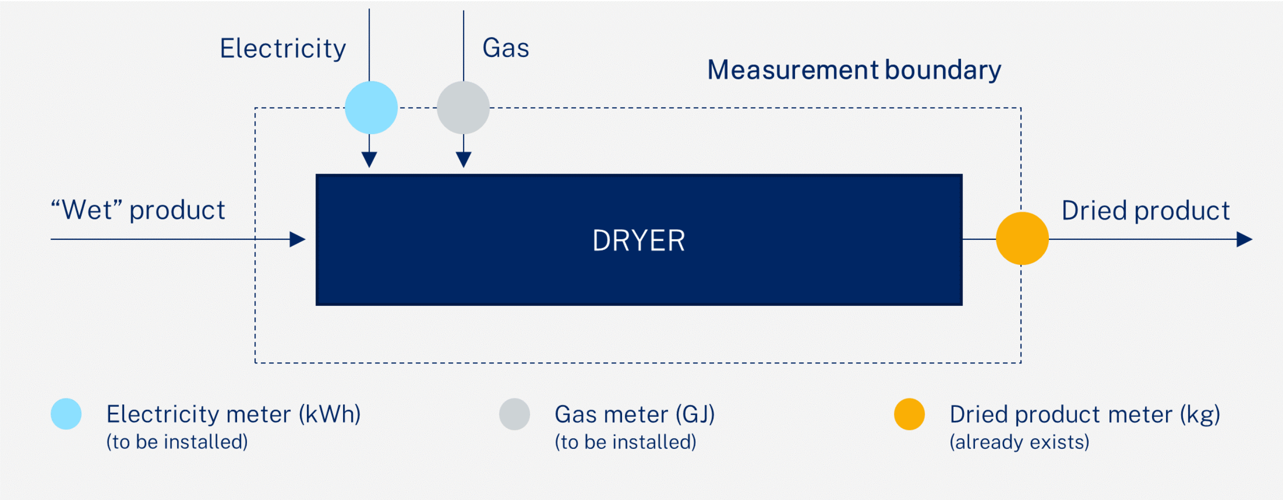
- Option A: key parameter measurement
- Option B: sub-metering of both electricity and gas consumption
- Option C: build a whole-of-site regression model.

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 much less than 5% for both annual electricity and gas consumption. As outlined earlier, it was not possible to build a whole-of-site regression model (IPMVP Option C) that had a sufficient high level of accuracy to determine the savings.

It was decided to install submetering (Option B) to determine savings. The installation is as shown in Figure 3, with the measurement boundary drawn exclusively around the dryer.

Figure 3 Measurement boundary



Data from the installed and existing meters would be analysed by the M&V practitioner 60 days after installation/commissioning to determine the baseline period.

Data availability

Available data included:

- daily weather data from the nearest Bureau of Meteorology (BOM) weather station
- day of the week. Each weekday could potentially be used as a binary variable
- daily production of dried (dehydrated) product (kg).

Data on the day-to-day variation in product mix was not available. It was confirmed that the overall mix had negligible month-to-month variations.

M&V budget

The preliminary M&V budget was estimated by the M&V practitioner as:

- $10,000 to develop the M&V plan
- $25,000 to install metering and connect it to the existing SCADA system
- $7,000 for the first M&V report including verification activities
- $4,000 annually (indexed for inflation) for ongoing verification of the savings and to prepare an annual M&V report.

Over a 10-year period, the estimated M&V cost would be $78,000 in 2019 dollars.

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:

- limitations of the available data and why submetering would need to be installed
- specifics of metering and the time needed to install and connect it to the SCADA system.

During this meeting, it was agreed that:

- the M&V budget for the plan and report was to be accepted. It was noted, there might be some variation depending on the exact cost of the gas metering installation.
- there would be a 60 day lead time to specify and install the gas metering. Installation would occur on weekend so as not to disrupt operations. Installation dates were set.
- data would be analysed 60 days after metering installation and a baseline period would be provided. The M&V plan would be presented following this.
- the whole installation process would take 3 weeks, including preparation to minimise operational disruptions:
  - a 5 day shutdown would be needed to install and commission the VSDs
  - new burners and controls would be installed during a scheduled 2 week site maintenance shutdown.

- the reporting period would begin after installation, commissioning and verification, it would be ongoing with a preliminary estimate of savings provided 3 months after installation.
- there were no upcoming planned changes to the dryer 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 the production manager by the M&V practitioner 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

Submeters were installed and, after some troubleshooting, were fully commissioned and reliably collected data within a month.

Potential independent variables

Potential independent variables were:

- temperature and relative humidity. This was determined using weather data collected from the nearest Bureau of Meteorology (BOM) weather station.
- daily kg of dried product exiting the dryer.
- the day of week as a binary variable.

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

Table 1 Sample of the potential independent variables

Date	Dry bulb temp (°C)	Humidity	kg dry product	Mon	Tue	Wed	Thu	Fri	Sat	Sun
30/05/2019	1.75	88.19	98026	0	0	0	1	0	0	0
31/05/2019	3.26	96.67	217416	0	0	0	0	1	0	0
1/06/2019	6.54	81.92	0	0	0	0	0	0	1	0
2/06/2019	6.16	86.19	0	0	0	0	0	0	0	1
3/06/2019	3.79	95.17	32623	1	0	0	0	0	0	0
4/06/2019	4.32	83.73	202931	0	1	0	0	0	0	0
5/06/2019	4.04	83.69	184592	0	0	1	0	0	0	0
6/06/2019	4.07	77.08	141698	0	0	0	1	0	0	0

Static factors

The static factors identified were:

- available dryer volume: 600 m^3
- dried product target moisture content: 9%
- number of fan motors: 4
- fan motor nameplate data: Teco 245 kW motors, 4 pole, IE class 2 motors, model number TC105785. All 4 motors are identical.

Interactive effects

There were no interactive effects since both gas and electricity consumption were modelled and there was no equipment outside the measurement boundary with energy use expected to vary because of the EEMs.

Meter details and accuracy

The electricity meter installed was an Allen Bradley, PowerMonitor 1000 (1408-TR2A-ENT)[1] with a EN62053-21:2003 Class 1 accuracy. This corresponds to an accuracy of ±1% at full load and with a power factor of 1. Accuracy deteriorates at lower loads and with a lower power factor.

Taking a conservative approach and assuming that the current transformers (CTs) were appropriately sized, it was assumed that the meter accuracy was ±2% of reading at the 95% confidence level. Details of the CTs used by the meter were not determined. Therefore it was not possible to know the loading conditions (as a percentage of full load) under which metering was undertaken.

The gas meter installed was an Endress+Hauser, Proline t-mass 65 (65F80-AK2AG1AAABCA).[2] This is a thermal mass flow rate meter (needing no compensation for temperature or pressure). It has an error of ±1.5% of reading for flow rates of between 10% to 100% of the design maximum mass flow rate of 2,030 kg/hr. This corresponds to a daily maximum flow rate of 2,439 GJ/day assuming constant full load (101.6 GJ/hr). Data was converted to MJ assuming a higher heating value (HHV) of 50.071 MJ/kg.

The actual HHV is not static and would vary over time, based on the mix of gases in the natural gas supplied to the site. However, as the HHV was not measured at any point, a simplifying assumption was that the HHV is constant at 50.071 MJ/kg. Typically, the HHV of natural gas could vary by up to 5% across a month.[3]

Based on the actual maximum daily gas consumption in the baseline period of 134 GJ/day, noting that the average hourly gas consumption is higher than this (the plant doesn't operate 24/7), the meter is likely to be measuring gas flow rates which, most of the time, are less than 25% of the maximum mass flow rate. This still corresponded to an accuracy of ±1.5% of reading.

[1] https://media.distributordatasolutions.com/Rockwell/files/File_PowerMonitor_1000_1408-IN001_EN_1.pdf
[2] https://www.endress.com/en/field-instruments-overview/flow-measurement-product-overview/t-mass-65f-thermal-mass-flowmeter?t.tabId=product-overview
[3] Based on hourly measurements of heating value in the Victorian gas network.

Considering there is also an error associated with the HHV of the gas, it was assumed that the gas meter had an error of ±5% at the 95% confidence level.

Data storage and transfer

Data in the SCADA system is backed up daily, to both local and cloud-based storage, and retained for 5 years.

For the purposes of M&V, it was agreed that the IT staff employed by the food manufacturer would set up a script to send the relevant data to the M&V practitioner daily. In turn, the M&V practitioner would set up scripts to automatically append this to a database related to this project.

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

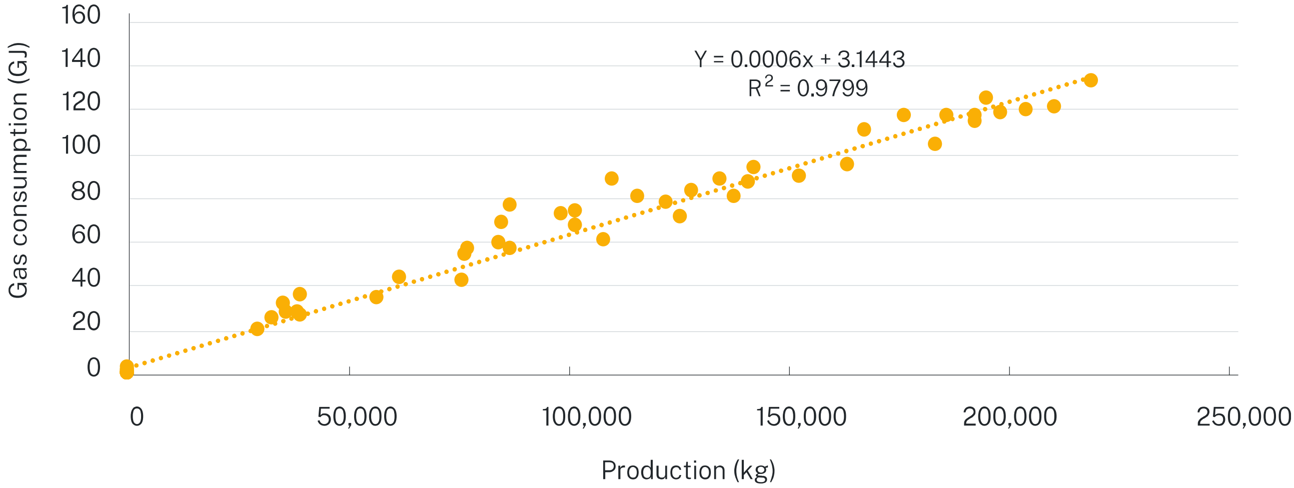
M&V Practitioner	Energy service provider	Energy user	Project sponsor
☑ Analyse data			

The M&V practitioner analyses the data to build a representative energy model. The M&V practitioner completed this analysis 60 days after the meters were installed. See below.

Data analysis for gas consumption: first 60 days

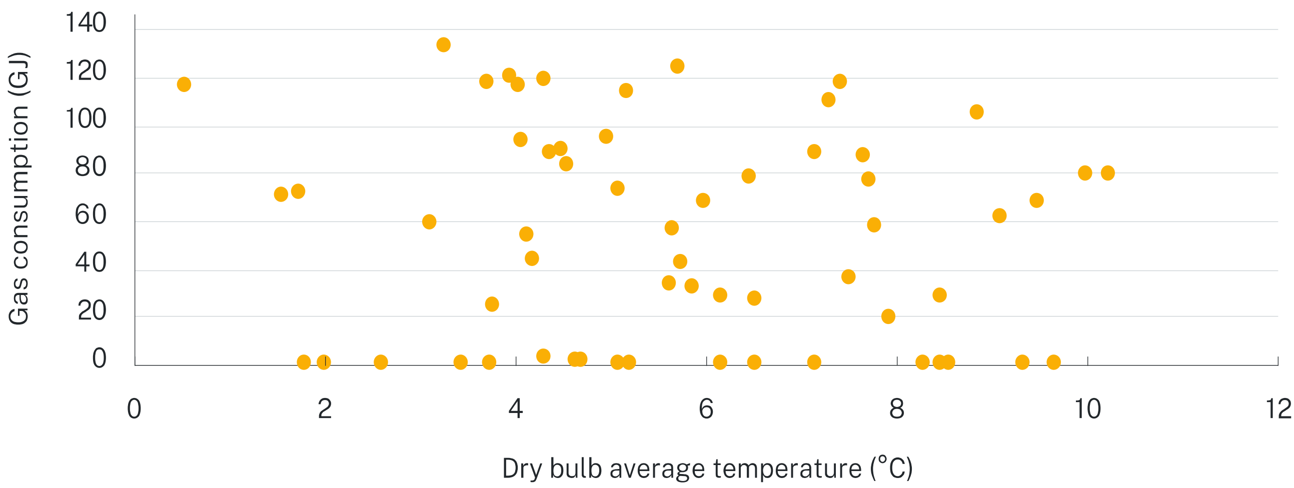
An acceptable regression model was built using the daily interval data with the kg of dried product (production) as the independent variable. This is shown in Figure 4.

Figure 4 Gas consumption versus production



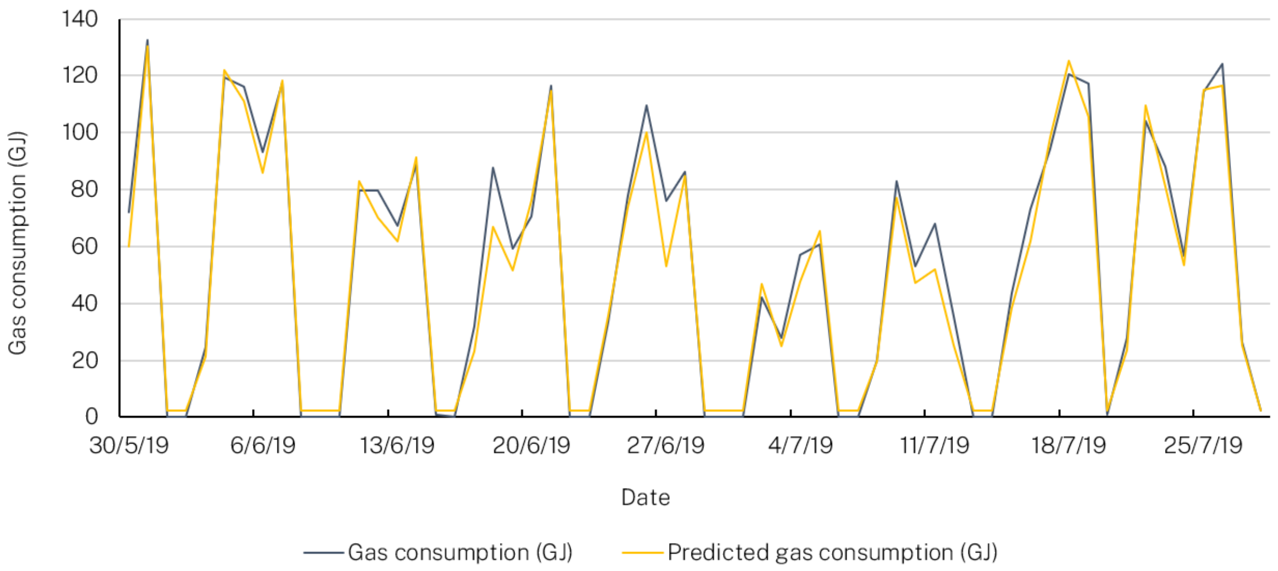
Given that the drying process involved heating, the M&V practitioner tested the relationship between gas consumption and outside temperature but found no clear correlation with outside temperature. This is shown in Figure 5.

Figure 5 Gas consumption versus dry bulb average temperature in first 60 days of baseline



Using production as the independent variable, the predicted versus actual gas consumption profiles in the first 60 days of the baseline are shown in Figure 6.

Figure 6 Actual and predicted gas consumption for the first 60 days of the baseline



The outcome of the initial data analysis and discussions with production manager confirmed there was:

- no real pattern during weekday production with gas consumption variations resulting from production variations
- low to no gas consumption on weekends when there is no production
- no seasonality in production schedule.

Data analysis for electricity consumption: first 60 days

Figure 7 shows a plot of electricity consumption versus kg of the dried products.

A regression model was, however, built using the daily interval data with the square root of the kg of the dried products as the independent variable. This is because using the square root of the kg of production results in a more "linear" regression whereby more of the data points are aggregated around the trendline.

The average temperature was tested and was found to be not a relevant independent variable because there was no correlation with electricity use, as shown in Figure 9.

Note: One of the data points for electricity showed a meter or data collection error, with zero electricity consumption recorded on one day, despite the dryer being in use that day. This data point was removed.

Figure 7 Electricity consumption versus kg of dried product, first 60 days of baseline

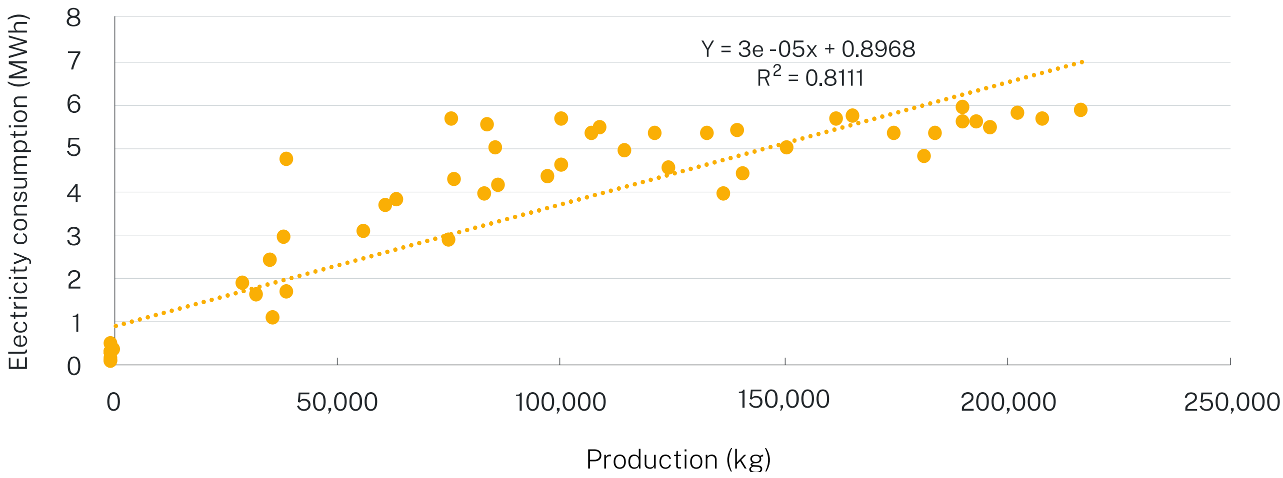


Figure 8 Electricity consumption versus square root of kg of dried product provides a more linear regression, first 60 days of baseline

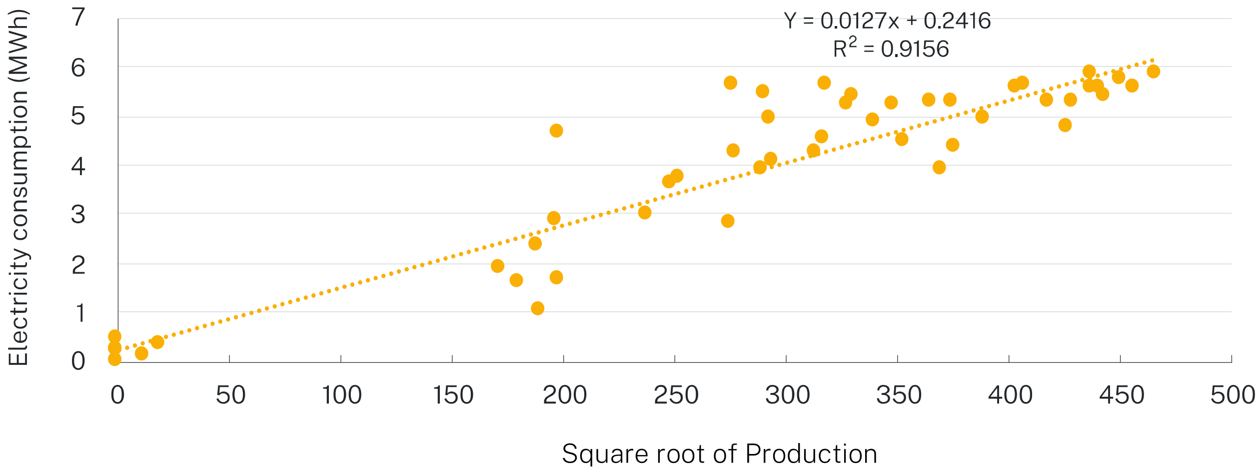


Figure 9 Electricity consumption versus dry bulb temperature, first 60 days of baseline

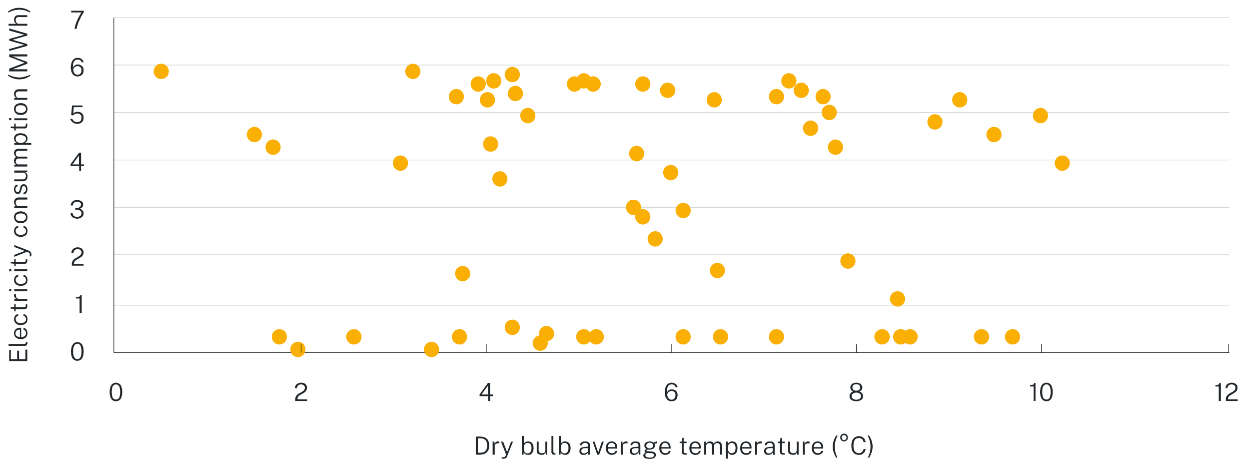


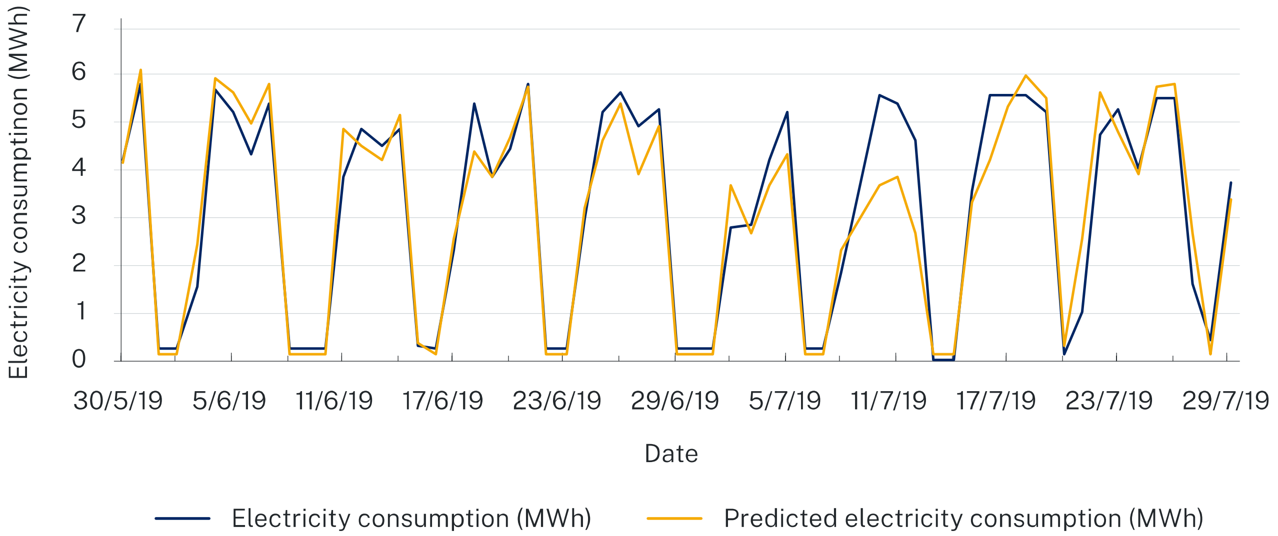
Figure 10 shows the predicted and actual energy consumption for the first 60 days of the baseline. Electricity consumption varies with a weekly cycle, with little or no consumption on weekends.

However, there is considerable variation in weekday consumption. This variation can be explained by the variation in the amount of production each day, although the error between predicted and actual consumption is occasionally large as can be seen in Figure 10.

It was not possible to identify if there were any other variables that might impact on electricity consumption. It was possible to build a regression model that showed less error by including selected individual days of the week as binary indicators.

The production manager could not explain why energy use may vary based on the day of week, therefore these were not included in the model as independent variables.

Figure 10 Predicted and actual electricity consumption for the first 60 days of the baseline



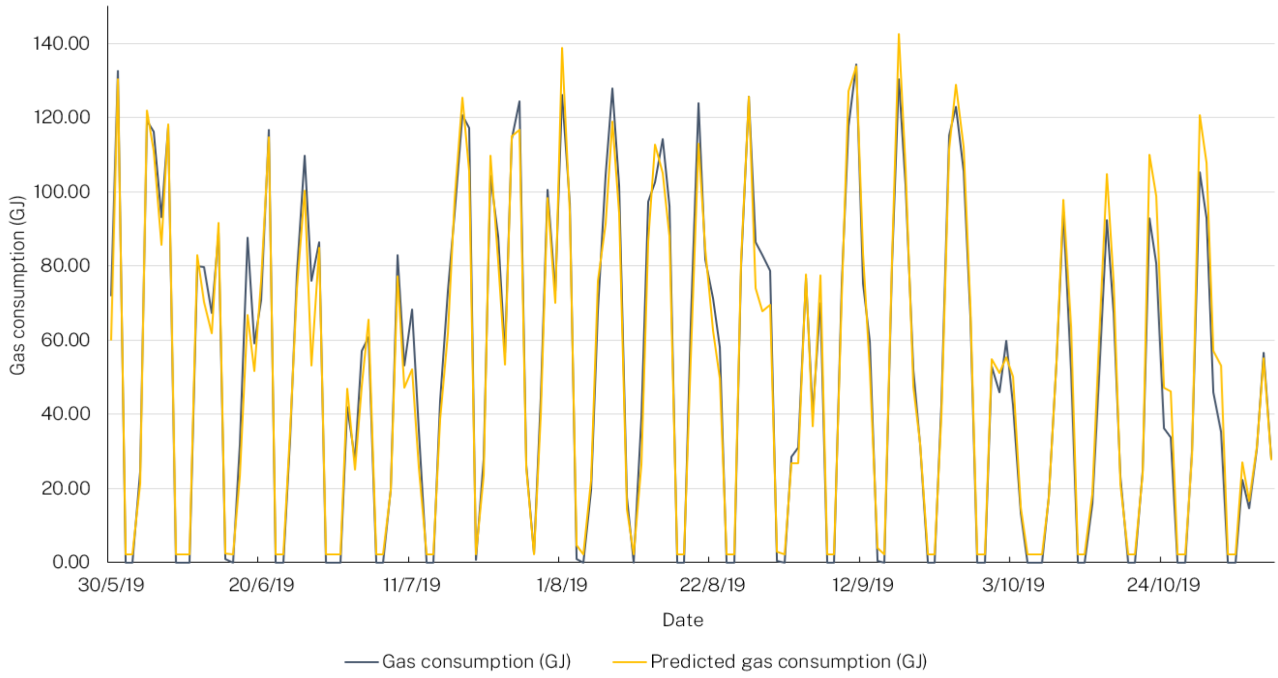
Baseline period

The M&V practitioner, production manager and energy services provider agreed that the baseline would run from 30 May 2019 to 8 November 2019. Data was collected without problem over this period. The gas and electricity baselines are described below.

Gas baseline

An acceptable regression was built using kg produced as an independent variable. Actual versus predicted gas consumption over the baseline is shown in Figure 11.

Figure 11 Baseline actual and predicted gas consumption



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

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

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

The baseline model relative precision, across all observations in the baseline, was calculated to be 1.8% at the 90% confidence level.

Note: Appendix B includes a plot of the residuals of the gas baseline model.

Table 2 Gas baseline model statistical test results

Parameter	Value	IPMVP recommendation	Acceptable?
Observations per independent variable	163	≥ 6	Yes
Expected values error	0.000%	< 0.005%	Yes
Adjusted R^2	0.97	> 0.75	Yes

Parameter	Value	IPMVP recommendation	Acceptable?
CV_{RMSE}	0.14	< 0.2	Yes

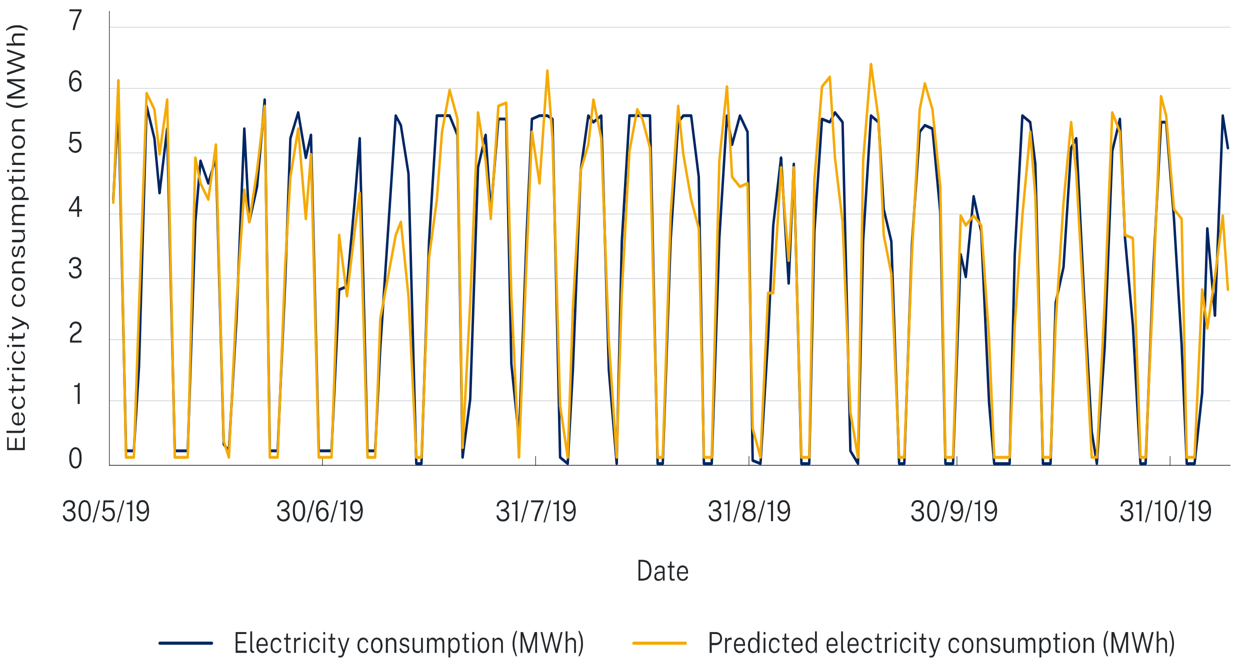
Table 3 Gas baseline model coefficients, t statistics, and range of independent variables

Parameter	Intercept	Kg of dry product
Coefficient	2.168	0.0006
t-statistic	2.57	76.73
t-statistic acceptable? (> |2|)	N/A	Yes
Minimum value	N/A	0
Maximum value	N/A	238042

Electricity baseline

An acceptable regression was built using the square root of kg produced as an independent variable. Actual versus predicted electricity use over the baseline is shown in Figure 12.

Figure 12 Electricity baseline actual and predicted electricity consumption



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

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

The model statistical test results are shown in Table 4 and Table 5.

The model's CV_{RMSE} was slightly greater than 0.2. All parties agreed to accept this, noting that:

- the M&V practitioner and production manager had been unable to identify any other variable that could explain the difference between actual and predicted energy consumption.
- it had been clearly established that weather variables were not suitable independent variables.
- including Saturday, Sunday and Monday as binary independent variables improved the model, reducing the CV_{RMSE} to less than 0.2, however they could not explain why these variables would influence electricity use of the dryer.
- this would result in a higher uncertainty of savings.

The range of independent variables in the model, and regression variable is shown in Table 5.

The baseline model relative precision, across all observations in the baseline, was 2.8% at the 90% confidence level.

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

Table 4 Electricity baseline model statistical test results

Parameter	Value	IPMVP recommendation	Acceptable?
Observations per independent variable	162	$\geq$ 6	Yes
Expected values error	0.000%	< 0.005%	Yes
Adjusted R^2	0.99	> 0.75	Yes
CV_{RMSE}	0.22	< 0.2	See discussion above.

Table 5 Electricity baseline model coefficients, t statistics, and range of independent variables

Parameter	Intercept	Square root of kg of dry product
Coefficient	0.145	0.013
t-statistic	1.53	38.76
t-statistic acceptable? (> |2|)	N/A	Yes
Minimum value	N/A	0
Maximum value	N/A	487.89

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 Intervals to align with weather data that is only available in daily intervals.
- ☑ Identify any missing data.
- ☑ Deal with missing data.
- ☑ Identify potential independent variables that could be used in the regression model.
- ☑ Develop 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 undertaken 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 models as summarised in tables 2 to 6 are deemed acceptable because:

- They met the recommended IPMVP statistical recommendations except for CV_{RMSE} for the electricity consumption model. However, all parties agreed to accept this as was described. above
- The expected savings were at least twice the expected savings' standard error as explained below.

The standard errors for the gas and electricity consumption baseline energy models were calculated as follows:

- gas: 1.1% (1.6% if autocorrelation is considered)
- electricity: 1.7% (2.2% if autocorrelation is considered).

The IPMVP requires that savings be at least twice the savings standard error.

Table 6 compares the expected savings versus the expected standard error to identify if expected savings are at least twice the expected savings' standard error.

Table 6 Determination of whether the expected savings are more than twice the expected savings standard error

Parameter	Gas (GJ)	Electricity (MWh)
Expected annual savings	4,000	300
Expected annual baseline consumption (based on 162 days of measurements)[4]	18,659	1,157
Expected savings as a per cent of annual consumption	21%	26%
Baseline model standard error per cent (allowing for autocorrelation)	1.6%	2.2%
Baseline submeter standard error*	0.2%	0.08%
Expected savings standard error per cent (allowing for autocorrelation)**	2.2%	3.1%
Expected savings as a multiple of expected standard error	9.5	8.5

[4] To create certificates, the Victorian Energy Upgrades (VEU) program and Energy Savings Scheme (ESS) prefer a 12-month baseline period. In this example it has been clearly demonstrated that weather had no significant impact on energy consumption and a shorter baseline period could be accepted. Reporting (operating) periods should really be 12 months long under these schemes.

Parameter	Gas (GJ)	Electricity (MWh)
Savings to standard error ratio > 2?	Yes	Yes

* The meter standard error is the error across all 162 measurements in the baseline. This is calculated by taking the meter percentage error from one observation (one day) and then dividing by the square root of 162, shown in Table 7 below for gas and electricity.

** Assumes the reporting period errors are identical to the baseline.

Table 7 Calculation of meter standard error

ID	Description	Formula	Gas (GJ)	Electricity (MWh)
A	Meter error (@95% confidence level)		5%	2%
B	t value @95% confidence level, assuming large degree of freedom		1.96	1.96
C	Meter standard error	A ÷ B	2.55%	1.02%
D	Number of baseline observations		162	162
E	Meter standard error across all observations	C ÷ √D	0.200%	0.080%

Checklist of activities and outcomes with notes where there are deficiencies

- ☑ The model satisfies certain statistical tests (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 manufacturing facility 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 (operating) period, it was agreed:

- the M&V practitioner would continue to receive data from the SCADA system
- the energy user would monitor changes in the static factors and advise the M&V practitioner of any expected or actual energy changes
- a preliminary analysis of savings would be presented 3 months into the reporting period. A final report on savings would be presented 12 months after the upgrade.

It was recommended that the M&V plan be assessed by a third-party expert for quality assurance (QA) before being approved. A third-party expert, 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 $1,500.

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)

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

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 complete, conservative and there were no additions or changes to be made. The M&V plan was approved.

Checklist of activities and outcomes with notes where there are deficiencies

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

In this example, it took 11 months from project initiation to approval as shown in Figure 13.

Figure 13 Schedule of activities undertaken in the baseline period

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
M&V kick off meeting											
Understand the EEMs and the likely savings											
Determine the M&V approach											
M&V meetings to finalise responsibilities and M&V budget											

Activity	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Meter specification, purchase and installation											
Baseline data collection											
Preliminary data analysis											
Complete the M&V plan											
Present the M&V plan											
Approve the M&V plan											
Installation of EEMs											

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 3 week period. After the burners and updated controls were installed, the M&V practitioner immediately visited the site to inspect the installation and verified it was operating as expected:

- staging of burners was as expected, with a much finer level of control than previously
- the burner fans were modulating as expected
- the control system was controlling the rate of fire of the burners correctly and the percentage of excess air varied little across the different firing rates.

After 3 months, the M&V practitioner analysed submeter interval data to determine if the savings matched what was expected. Those savings are compared in Table 8.

Table 8 Comparison between predicted savings with those calculated for first 3 months of the reporting period

Parameter	Gas	Electricity
Percentage savings in first 3 months (%)	26%	19%
Percentage of expected savings (%)	21%	26%

Gas savings in the first 3 months were higher than expected, while electricity savings were lower. In discussions with the energy user and energy services provider, it was not possible to identify why the initial savings were different to that which was expected. The conclusion was that energy auditors made several assumptions when estimating the savings that were not realised.

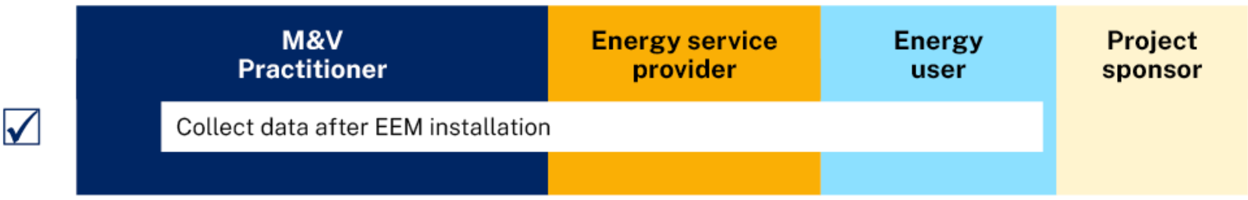
Based on this preliminary analysis, the M&V practitioner suggested that electricity savings over 12 months could be lower than expected and gas savings could be higher.

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 continued to engage with the production manager 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 static factors.

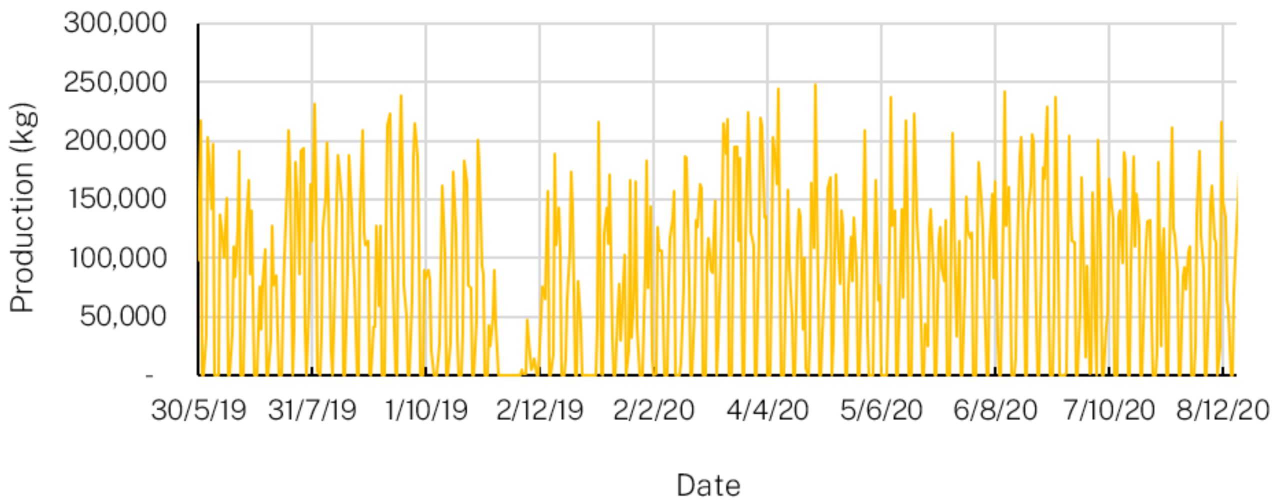
Step 13 Savings determination

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

Reporting period energy use

Data was collected for more than 18 months following the upgrade, as shown in Figure 14.

Figure 14 Daily production of dry product, before and going into COVID. It is noticed that production was not impacted by COVID restriction measures. The drop in production in November 2019 occurs during the shutdown in which the EEMs were installed



COVID-19 impacts: in Australia, the COVID-19 pandemic impacts started from mid-March 2020, however the facility management reported there were no changes in the site constants due to COVID-19. This is because the food manufacturing facility 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 for a Non-Routine Adjustment (NRA).

Reporting period regression model

Using the same set of independent variables chosen for the baseline period energy models, energy models for gas and electricity consumption in the reporting period were built using regression analysis, as shown in Figure 15 and Figure 16.

Figure 15 Daily actual and predicted gas consumption in the reporting period

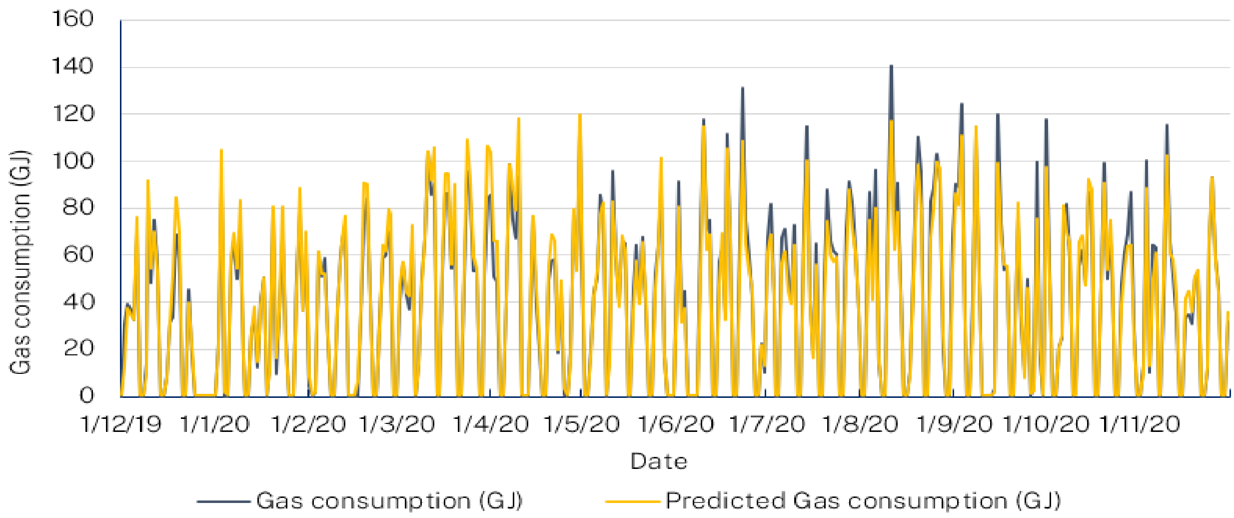
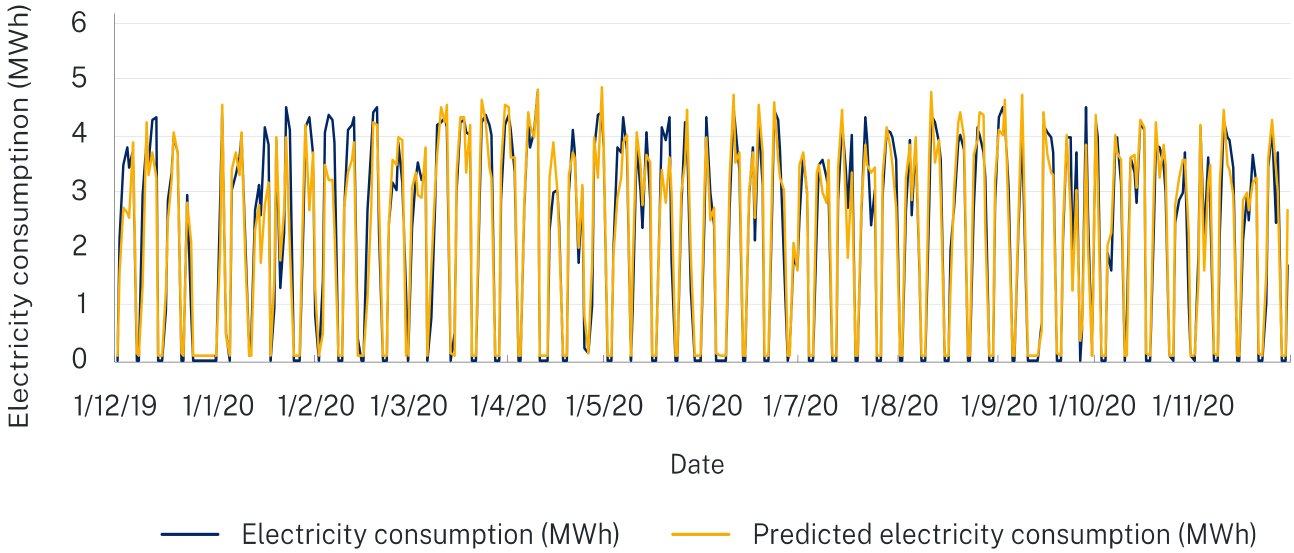


Figure 16 Daily actual and predicted electricity consumption in the reporting period



Acceptability of the reporting period energy model

Tables 9 to 12 show that the models largely satisfy the IPMVP statistical recommendations for regression analysis. This means the reporting period energy models are ‘acceptable’.

Table 9 Gas reporting model statistical test results

Parameter	Value	IPMVP recommendation	Acceptable?
Observations per independent variable	366	$\geq$ 6	Yes
Expected values error	0.000%	< 0.005%	Yes
Adjusted R^2	0.96	> 0.75	Yes
CV_{RMSE}	0.18	< 0.2	Yes

The relative precision for the reporting period gas model across all observations in the baseline was 1.5% at the 90% confidence level.

Table 10 Gas reporting model coefficients, t statistics, and range of independent variables

Parameter	Intercept	kg of dry product
Coefficient	0.84	0.0005
t-statistic	1.51	92.95
t-statistic acceptable? (> |2|)	N/A	Yes
Minimum value	N/A	0
Maximum value	N/A	247606

Table 11 Electricity reporting model statistical test results

Parameter	Value	IPMVP recommendation	Acceptable?
Observations per independent variable	366	$\geq$ 6	Yes
Expected values error	0.000%	< 0.005%	Yes
Adjusted R^2	0.91	> 0.75	Yes
CV_{RMSE}	0.22	< 0.2	See earlier discussion as to why all parties agreed to accept a high CV_{RMSE}.

The relative precision for the reporting period electricity model across all observations in the baseline was 1.9% at the 90% confidence level.

Table 12 Electricity Reporting model coefficients, t statistics, and range of independent variables

Parameter	Intercept	Square root of kg of dry product
Coefficient	0.103	0.01
t-statistic	2.37	62.28
t-statistic acceptable? (> |2|)	N/A	Yes
Minimum value	N/A	0
Maximum value	N/A	497.60

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 2020 as the normal year. This was identified as being reflective of the expected typical operation of the site in the future, with the facility 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 17 and Figure 18.

Figure 17 Baseline and reporting gas energy adjusted to normal conditions

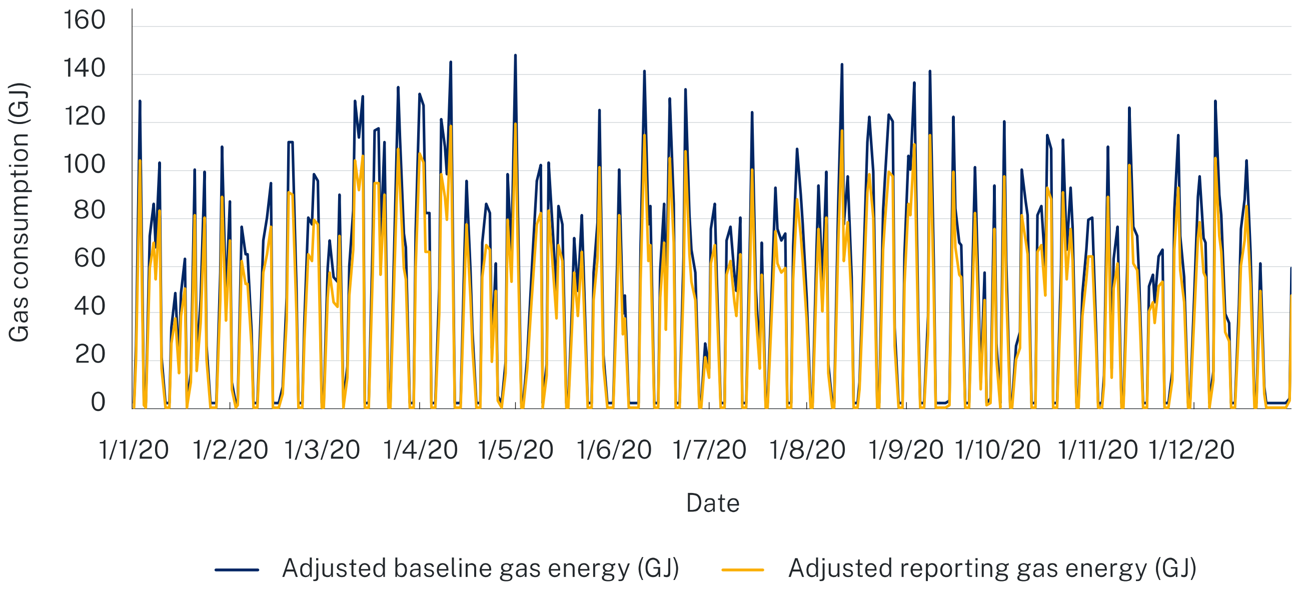
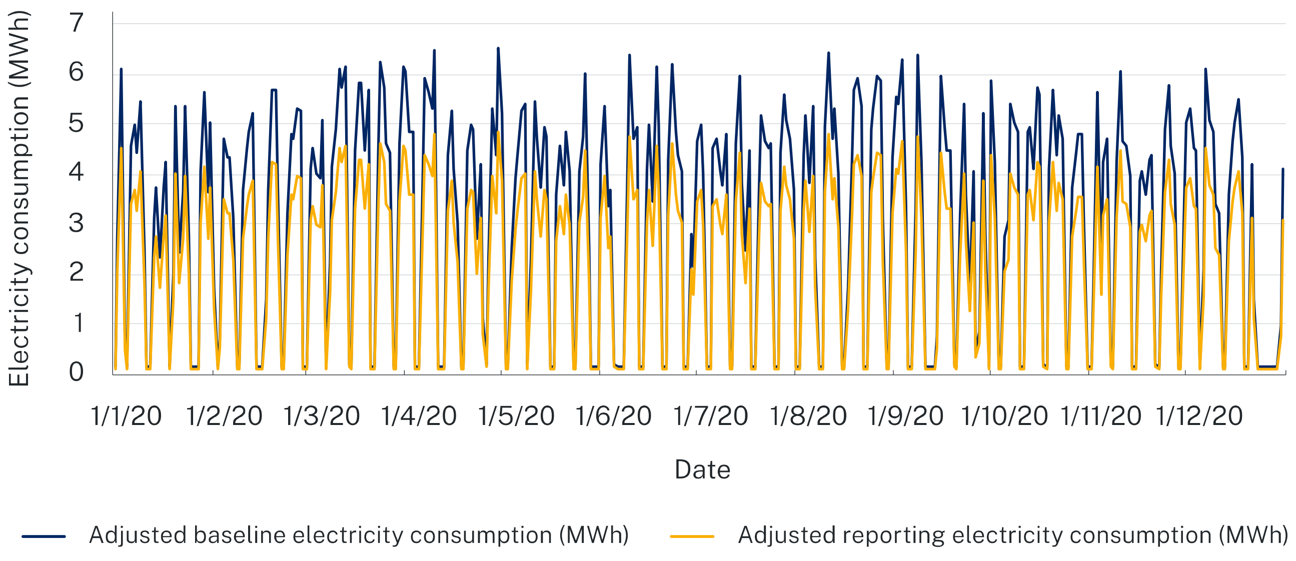


Figure 18 Baseline and reporting electricity consumption adjusted to normal conditions



The range of independent variables in the normal year, baseline period and reporting period are very similar as shown in Table 13.

Table 13 Range of independent variables in the normal year, baseline period and reporting period

Parameter		Gas model, kg of dry product	Electricity model, square root of kg of dry product
Baseline period	Min	0	0
	Max	238,042	487.90
Reporting period	Min	0	0
	Max	247,606	497.60
Normal year	Min	0	0
	Max	247,606	497.60

As the variation in range between the reporting period, normal year and the baseline period was less than 10%, the baseline and reporting models were deemed to be acceptable across all observations in the normal year (IPMVP has no firm guidance, this is a requirement of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Guideline 14-2014 Measurement of Energy, Demand and Water Savings.[5]

Savings were determined to be 20% and 26% of the (adjusted) baseline gas and electricity use respectively, as shown in Table 14. Expected savings before the project were estimated to be $106,000 with actual savings slightly lower at around $101,000. The gas savings were lower than expected based on the first 3 months of the reporting period, but electricity savings were higher. No reason could be established by the M&V practitioner for the variation. Overall savings were only slightly lower than initially expected at the start of the project.

Table 14 Savings determination

Parameter	Gas (GJ)	Electricity (MWh)
Total adjusted baseline energy	18,425	1,131
Total adjusted reporting energy	14,709	838
Total normalised savings	3,717	293
Savings as a percentage of the adjusted baseline	20%	26%
Error in savings determination at the 90% confidence level	592	45

[5] ASHRAE Guideline 14-2014 Measurement of Energy, Demand and Water Savings. Approved by ASHRAE on December 18, 2014. © 2014 ASHRAE ISSN 1049-894X

Parameter	Gas (GJ)	Electricity (MWh)
Relative precision*	16%	15%
Baseline tariff ($/energy unit)	$10.70	$210.00
Monetary savings $	$39,767	$61,630
Total savings $	$101,397	

* 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. Table 16 details how the relative precision was calculated.

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 are outlined in Table 15.

Table 15 Components of error in savings determination

Parameter	Gas	Electricity
Baseline model standard error percent (allowing for autocorrelation)	1.6%	2.2%
Baseline submeter standard error	0.20%	0.08%
Baseline overall standard error	1.6%	2.2%
Reporting period model standard error percentage (allowing for autocorrelation)	1.4%	1.4%
Reporting period submeter standard error	0.13%	0.05%
Reporting period overall standard error	1.4%	1.4%

Table 16 Calculation of relative precision

ID	Description	Gas (GJ)	Electricity (MWh)	Formula
A	Total adjusted baseline energy	18,425	1,131	
B	Total adjusted reporting energy	14,709	838	
C	Total normalised savings	3,717	293	A – B
D	Baseline standard error	1.6%	2.2%	
E	Baseline degrees of freedom	160	160	

ID	Description	Gas (GJ)	Electricity (MWh)	Formula
F	Baseline standard error	293	24.5	A x D
G	Baseline error @ 90% confidence level	484	40.5	F x 90% t value @ E degrees of freedom
H	Reporting standard error	1.4%	1.4%	
I	Reporting degrees of freedom	364	364	
J	Reporting standard error	206.62	11.81	B x H
K	Reporting error @ 90% confidence level	341	19.5	J x 90% t value @ I degrees of freedom
L	Overall standard error	358	27.2	$\sqrt{(F^2 + J^2)}$
M	Overall error @ 90% confidence level	592	44.9	$\sqrt{(G^2 + K^2)}$
N	Relative precision	16%	15%	M ÷ C

Note: the errors above are based on the number of observations in the baseline and reporting models respectively.

The IPMVP requires annual savings to be more than twice the standard error. In this example, both electricity and gas savings are more than twice the standard error.

Savings were $5,000 less than the initial estimate of $106,000. Interestingly, gas savings were lower than expected 3 months into the reporting period, while electricity savings were higher. No reason for the variation could be established by the M&V practitioner.

Table 17 Expected and actual savings

Parameter	Gas	Electricity
Units	GJ	MWh
Expected energy savings	4,000	300
Actual savings	3,717	293
Difference	-283	-7
Percentage difference	-7%	-2%

Checklist of activities and outcomes with notes where there are deficiencies

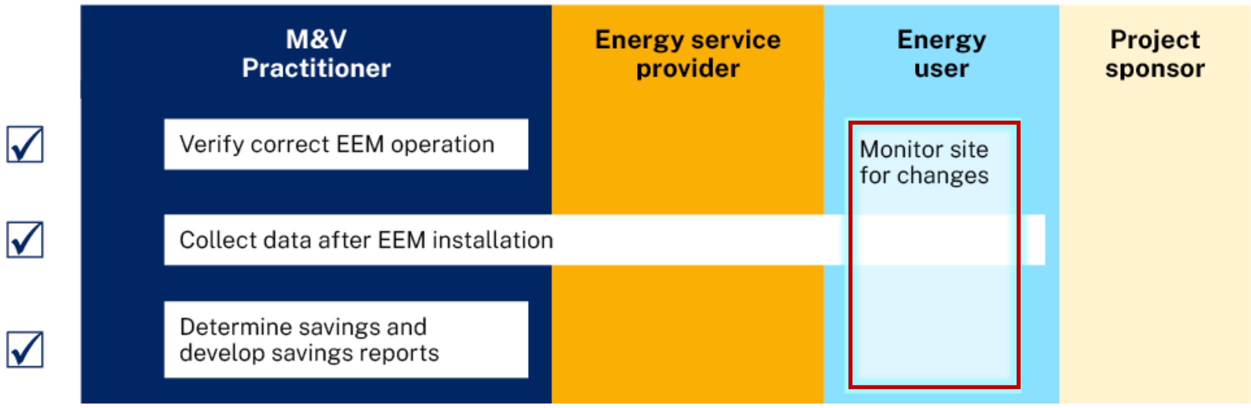
- ☑ Identify the period over which savings are to be reported.
- ☑ Determine the basis by which savings will be calculated.
- ☐ Complete non-routine adjustments to account for unexpected changes at the site, unrelated to the EEM, which may cause energy use to increase or decrease.

  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 use.

In this example, the food manufacturer agreed to continue the ongoing monitoring, verification and reporting of energy savings. It was agreed tracking the dryer gas and electricity consumption every 3 months would enable the ongoing verification of the expected savings.

The annual cost of conducting ongoing monitoring and reporting was $4,000. This included plotting, on an ongoing basis, a graph showing the cumulative sum ('cusum') of savings from the EEMs. The 'cusum' graphs for gas and electricity over the first 12 months of the reporting period are shown in Figure 19 and Figure 20.

Cumulative sum, or 'cusum' Is a bar or line chart showing the ongoing cumulative sum over time. ‘Cusum’ profiles of energy savings, in particular, clearly Indicate the change In calculated savings over time and can be utilised to detect anomalies in calculated energy savings during any period. The slope of the cumsum line reflects the rate by which the energy savings are accumulating, with a steady upward slope indicating a constant amount of savings is being added in each time step. Any change in this cumsum slope means a change in savings' rate.

It was also agreed to perform a quarterly monitoring process for any deviations. 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 monitor whether the EEMs have continued to perform as expected.

Figure 19 Cumulative sum (‘cusum’) of gas savings

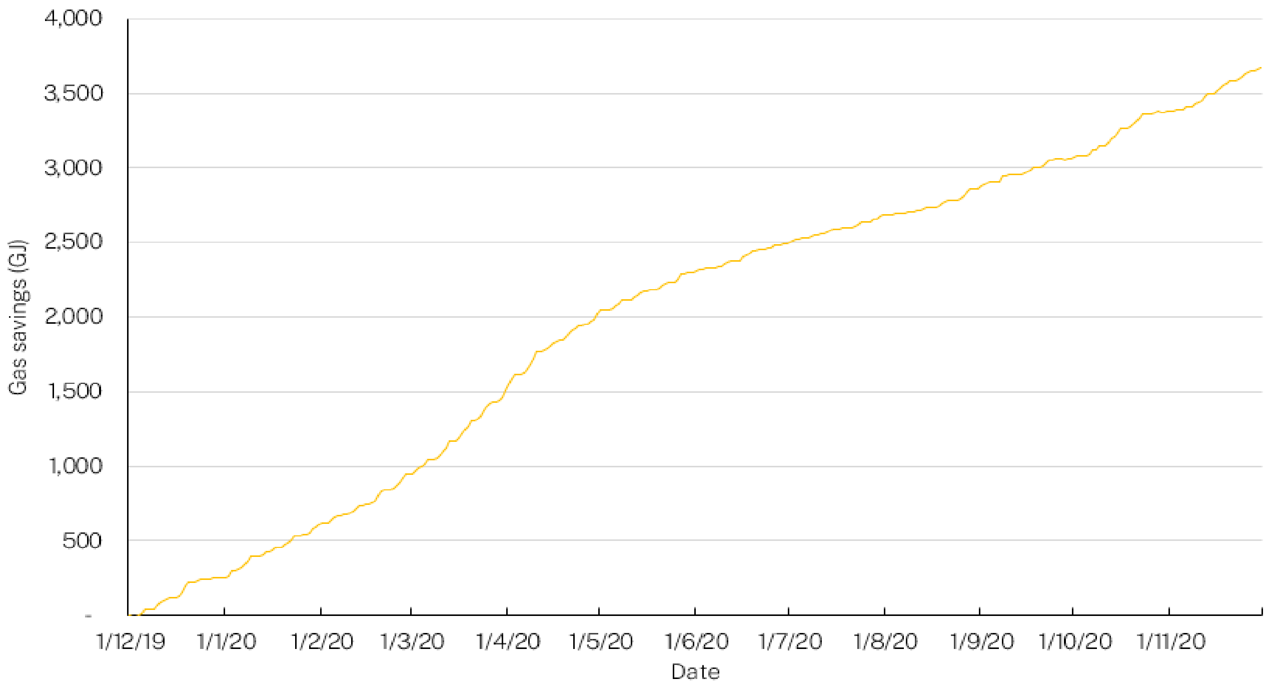
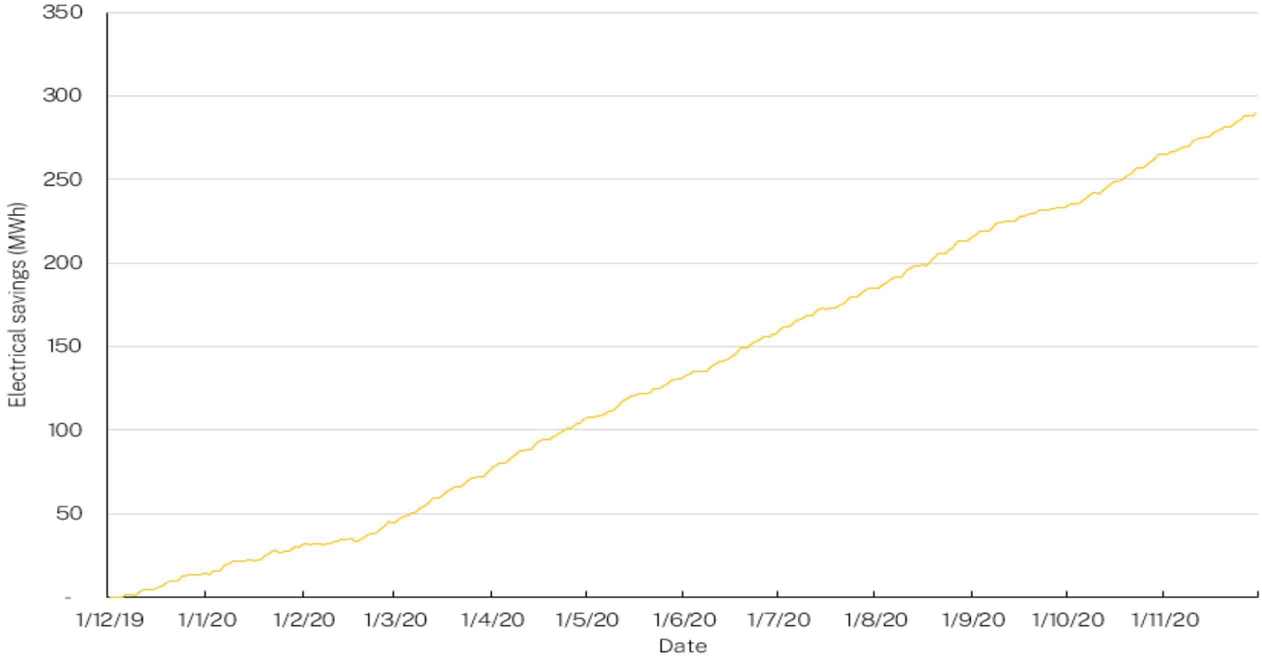


Figure 20 Cumulative sum ('cusum') of electricity savings. Note how the rate of savings appears to increase from the start of March. The M&V practitioner could not determine a reason for the increase.



It was agreed that if a deviation greater than 5%[6] from the expected dryer electricity or gas use occurred, the M&V practitioner would follow up 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.

If there are no site changes (to static factors), but quarterly energy use deviated by more than 5% of expected energy use, then the M&V practitioner could request an inspection of the dryer and burners to see if the burners were continuing to operate as intended.

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

The food manufacturer also agreed to continue to track any planned or unplanned changes on site that might cause changes to energy use.

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

☑ Determine ongoing tracking of savings. A cumulative sum of savings graph which should show cumulative savings continually increasing over time, can be an effective way of communicating the savings resulting from the EEMs.

[6] With gas savings of 20%, a 5% variation in expected energy use is around ¼ of the savings.

☑ Monitor changes to static factors (i.e. non-routine events).

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 2 weeks after the submission of the first savings report. The following discussions took place:

- The installation of the submeters enabled the determination of savings to a reasonably high level of accuracy. The requirement by the production manager that savings be determined with a relative precision of 20% or less was met (actual relative precision was 16% for gas and 15% for electricity).
- The savings were a little less than what was estimated in the energy audit report. The M&V practitioner advised that the equipment appeared to be operating as intended and the relatively small error (less than 10% of expected savings) meant that the initial savings estimate in the energy audit was pretty good.
- The M&V process was seen as beneficial by all parties. While the savings were not quite as high as expected, the food manufacturer management was happy with the level of M&V and the advice provided by the independent expert on the M&V plan.
- The production manager concluded that the main benefit of the M&V was that it helped establish the savings in a way that was trustworthy. 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.
- The 'cusum' graphs of gas and electricity savings provided useful feedback on whether the EEMs continue to perform as expected. The production manager agreed that any noticeable reduction in the rate of savings (the slope of the 'cusum' graphs) would clearly show that there was a loss of savings.

Checklist of activities and outcomes with notes where there are deficiencies

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

- ☑ Discuss what benefits the M&V process provided.
- ☑ Discuss what would be done differently if you were doing again.

For more information about the Energy Security Safeguard

Visit: www.energy.nsw.gov.au

Email: sustainability@environment.nsw.gov.au