Department of Climate Change, Energy, the Environment and Water

Measurement and verification demonstration project

Food manufacturer: Appendices A and B

August 2024

NSW GOVERNMENT

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

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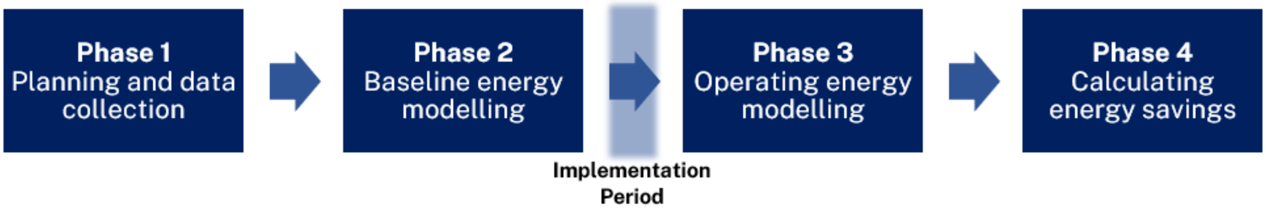
Appendix A

Calculating energy savings under the Energy Savings Scheme

Under the Energy Savings Scheme (ESS), energy savings are calculated using the Project Impact Assessment with Measurement and Verification (PIAM&V) method. This method uses M&V principles to compare modelled energy consumption before implementing with either modelled[1] or measured[2] energy consumption after the implementation.

The PIAM&V method is designed to be completed progressively in 4 key phases as illustrated in figure A1.

Figure A1 PIAM&V phases



The energy savings calculated in phase 4 are then converted into Energy Savings Certificates (ESCs) under the ESS. Each phase is detailed below.

Phase 1: Planning and data collection

Understanding End-User Equipment (EUE)

In this case, the energy savings were achieved through the following system upgrades:

- replacing the gas dryer burners with more efficient burners
- fitting variable speed drives (VSDs) to the burner fans
- upgrading the dryer sensors and controls.

Measurement boundary

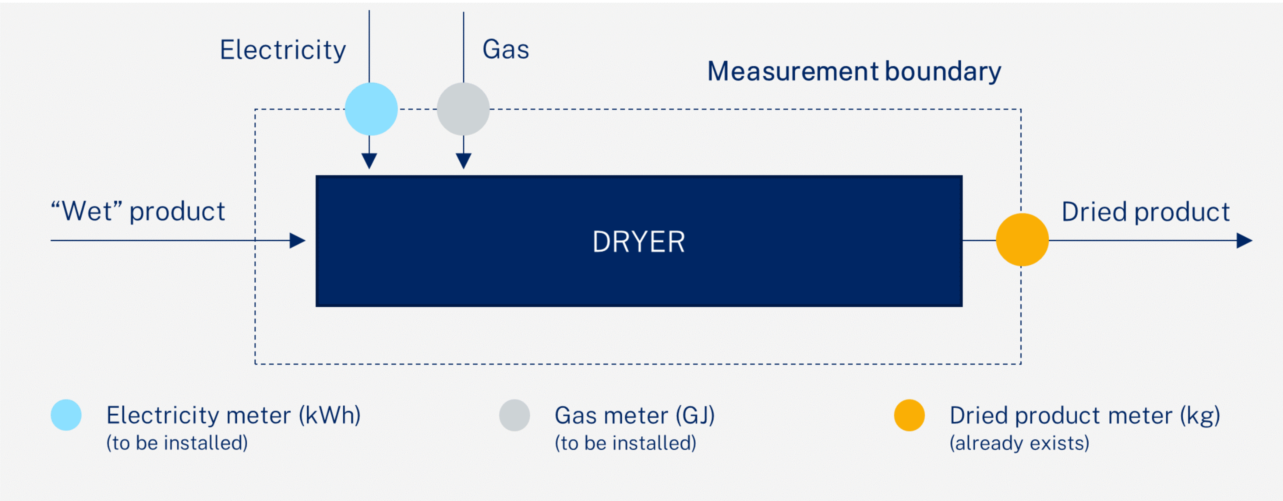
The expected savings are much less than 5% of both annual electricity and gas consumption.

1 For forward creation of ESCs
2 For annual creation of ESCs

The M&V practitioner confirmed the best way to accurately capture the savings is by Installing submetering on the upgraded equipment and use retrofit isolation approach as the optimal choice of the measurement boundary, i.e., International Performance Measurement and Verification Protocol (IPMVP) Option B.

It was decided to install submetering as shown in figure A2, with the measurement boundary drawn exclusively around the dryer system. The same measurement boundary was used for the gas and electricity modelling.

Figure A2 Measurement boundary



Independent variables and site constants

Regression analysis was used to develop the baseline and operating energy models. The selected independent variables were:

- daily kg of dried product exiting the dryer
- daily operating status as a binary variable.

The excluded independent variables were average temperature and humidity due to poor correlation with gas and electricity consumption.

The selected site constants were:

- available dryer volume: 600 m^3
- dried product target moisture content: 9%
- number of dryer 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).

Measurement period and operating cycle

Since the gas and electricity use did not vary with ambient temperature, the operating cycle chosen could be less than 12 months.

To gauge the appropriate length of the baseline measurement period, the submeter data was analysed 2 months after installation. This was to attempt to build a statistically valid energy model for both gas and electricity.

The resulting 60 day baseline energy model was successful in modelling the gas and electricity consumption based on production data variation. However, some unexplained variations in the energy profile were observed in the 60 day energy model.

A 6 month measurement period was chosen to ensure the baseline energy model captured a complete operating cycle. This allowed the team to capture periods where production significantly increased. A longer measurement period (12 months) was selected for the operating period for similar reasons and to allow for a more representative effective range.

Measurement procedures

It took a month to install and fully commission the electricity and gas submeters and to start collecting reliable data. Independent variables data provided by the energy user included:

- day of week (each day as a binary variable)
- daily kg of dried product exiting the dryer.

During the 6 month baseline measurement period, energy consumption and the independent variables were measured daily. This continued for a 12 month period during the operating measurement period.

The chosen measurement periods were reasonable because they included time periods during which independent variables might reasonably be expected to cause the implementation to increase energy consumption.

Engaging an M&V professional

A third-party M&V professional was contracted to review the M&V plan and confirm that the measurement procedures were appropriate.

Phase 2: Baseline energy modelling

Modelling the baseline energy consumption

Regression analysis was used to develop a daily baseline energy model using the parameters identified in Phase 1. The baseline measurement period, for both the gas and electricity modelling, was chosen to be 6 months, from 30 May 2019 to 8 November 2019. This ensured the inclusion of a complete operating cycle of the site gas and electricity consumption.

No non-routine events were identified during the baseline measurement period and therefore no non-routine adjustments were required to the baseline energy model.

The M&V professional reviewed the M&V plan and the measurement procedures for the baseline energy model and commended the M&V practitioner for the conservative selection of the baseline period.

Gas modelling

The following formula describes the relation between the dependent variable (gas consumption) and the independent variable:

Daily gas consumption (GJ) = 2.168 + 0.0006 x (kg dried product)

The baseline energy model statistics including the range of the independent variables, t-statistics, CV_{RMSE}, and adjusted R^2 are shown in tables A1 and A2.

Table A1 Gas baseline model statistical test results

Parameter	Value	ESS requirement	Acceptable?
Observations per independent variable	163	$\geq$ 6	Yes
Adjusted R^2	0.97	$\geq$ 0.5	Yes
CV_{RMSE}	0.14	< 0.25	Yes

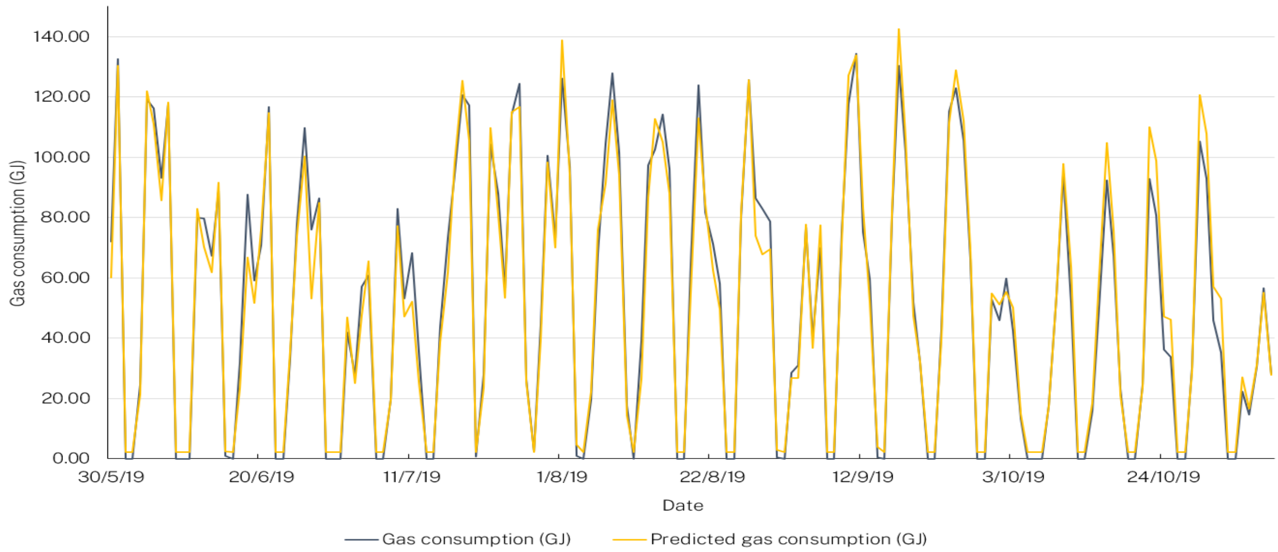
Table A2 Gas baseline model coefficients, t-statistics and range of independent variables of choice

Parameter	Intercept	kg of dry product
Coefficient	2.168	0.0006
t-statistic	2.57	76.73
t-statistic acceptable? (> |2|)	N/A	Yes

Parameter	Intercept	kg of dry product
Minimum value	N/A	0
Maximum value	N/A	238042

Figure A3 shows the gas consumption predicted by the baseline energy model compared to the actual gas consumption.

Figure A3 Baseline actual and predicated gas energy (GJ)



Electricity modelling

A regression analysis using the square root of kg produced as an independent variable was applied.

The following formula describes the relation between the dependent variable (electricity consumption) and the independent variable:

Daily electricity consumption (kWh) = 0.145 + 0.013 x (square root of kg dried product)

The electricity baseline energy model statistics including the range of the independent variables, t-statistics, CV_{RMSE}, and adjusted R^2 are shown in tables A3 and A4.

Table A3 Electricity baseline model statistical test results

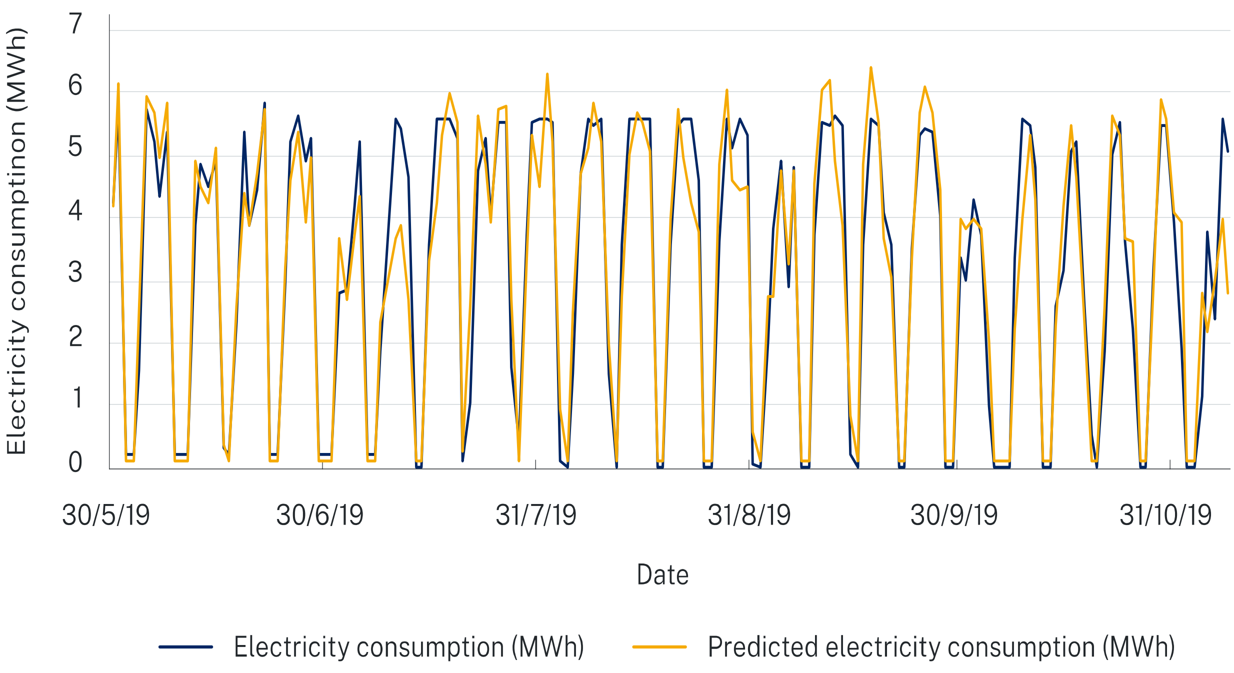
Parameter	Value	ESS requirement	Acceptable?
Observations per independent variable	162	≥ 6	Yes
Adjusted R^2	0.90	≥ 0.5	Yes
CV_{RMSE}	0.22	< 0.25	Yes

Table A4 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

Actual versus predicted electricity consumption over the baseline measurement period is shown in figure A4.

Figure A4 Baseline actual and predicted electricity consumption



Tip: Choosing a conservative baseline mitigates the risks to the business and increases the chances that the M&V plan will be accepted

Phase 3: Operating energy modelling

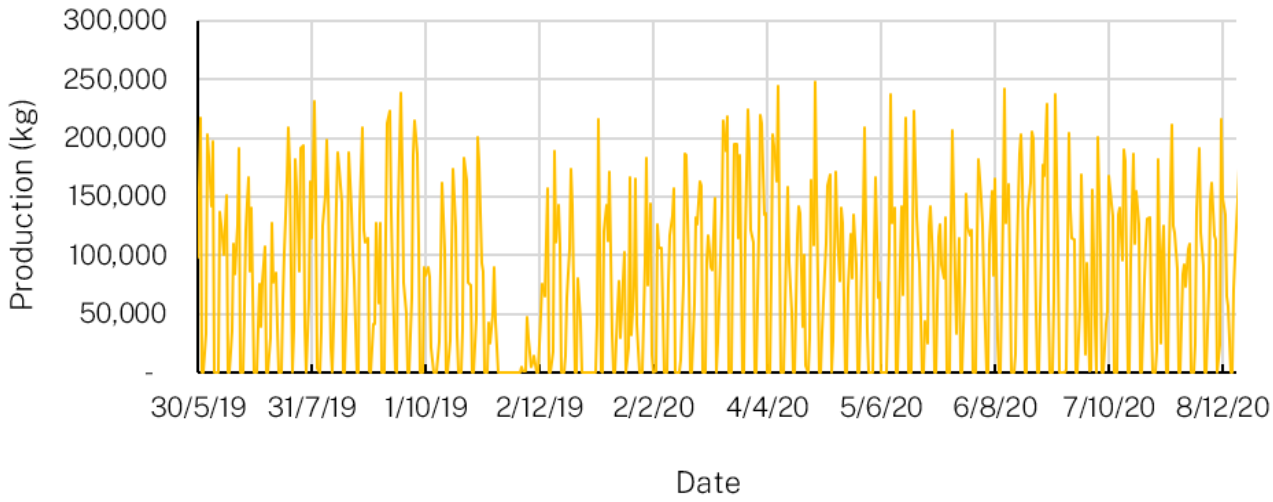
Modelling the operating energy consumption

The installation and commissioning of the 3 upgrades took place over a period of 3 weeks, with an implementation date of 30 November 2019. The parameters identified in Phase 1 were used to develop a daily operating energy model and the operating measurement period selected was from 1 December 2019 till 30 November 2020.

Production remained largely unchanged, exhibiting similar daily variation before and at the start of COVID-19 in mid-March 2020. This was because the facility continued to operate throughout COVID-19 as an essential service. Figure A5 shows the daily production of dry product, before and going into the COVID-19 period.

The drop in production noticed in November 2019 occurred during the shutdown when the energy efficiency measures (EEMs) were installed.

Figure A5 Daily kgs of dry product



The M&V practitioner consulted the PIAM&V Method Application Requirements for Non-Routine Events and Adjustments and determined that there was no need for a non-routine adjustment.

Gas modelling

The following formula describes the relation between the dependent variable (gas consumption) and the independent variable:

Daily gas consumption (GJ) = 0.84 + 0.0005 x (kg dried product)

The operating energy model statistics including the range of the independent variables, t-statistics, CV_{RMSE}, and adjusted R^2 are shown in tables A5 and A6.

Table A5 Gas operating model statistical test results

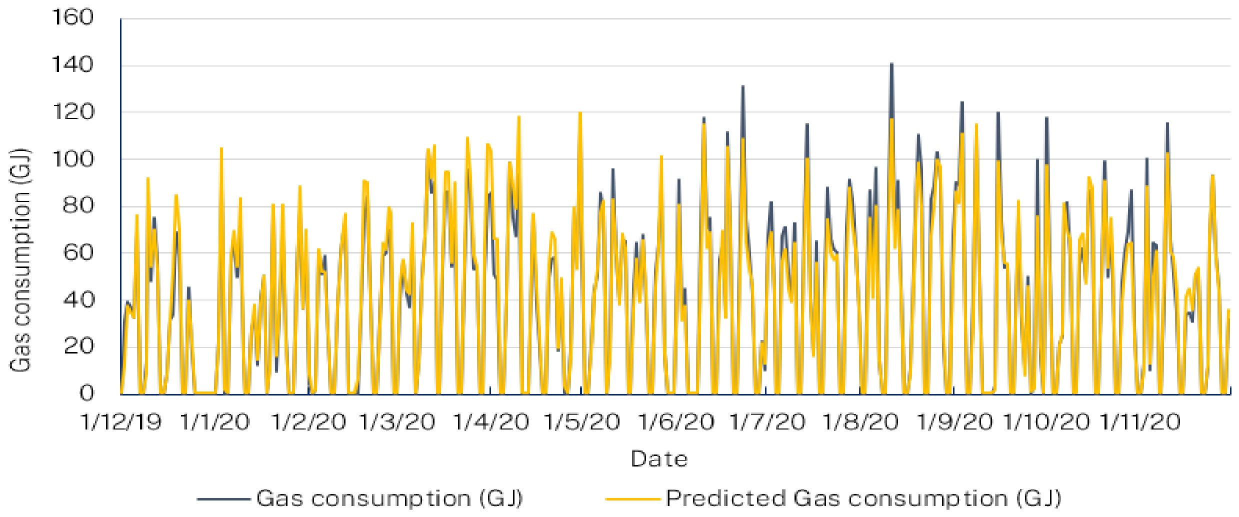
Parameter	Value	ESS requirement	Acceptable?
Observations per independent variable	366	$\geq$ 6	Yes
Adjusted R^2	0.96	$\geq$ 0.5	Yes
CV_{RMSE}	0.18	< 0.25	Yes

Table A6 Gas operating model coefficients, t-statistics and range of independent variables of choice

Parameter	Intercept	Average temperature
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

Figure A6 shows the electricity consumption predicted by the operating energy model compared to the actual electricity consumption.

Figure A6 Daily actual and predicted gas usage in the reporting period



Electricity modelling

The following formula describes the relation between the dependent variable (electricity consumption) and the independent variable:

Daily electricity consumption (kWh) = 0.103 + 0.01 x (Square root of kg dried product)

The operating energy model statistics including the range of the independent variables, t-statistics, CVRMSE, and adjusted R2 are shown in tables A7 and A8.

Table A7 Electricity reporting model statistical test results

Parameter	Value	ESS requirement	Acceptable?
Observations per independent variable	366	$\geq$ 6	Yes
Adjusted R^2	0.91	$\geq$ 0.5	Yes
CV_{RMSE}	0.22	< 0.25	Yes

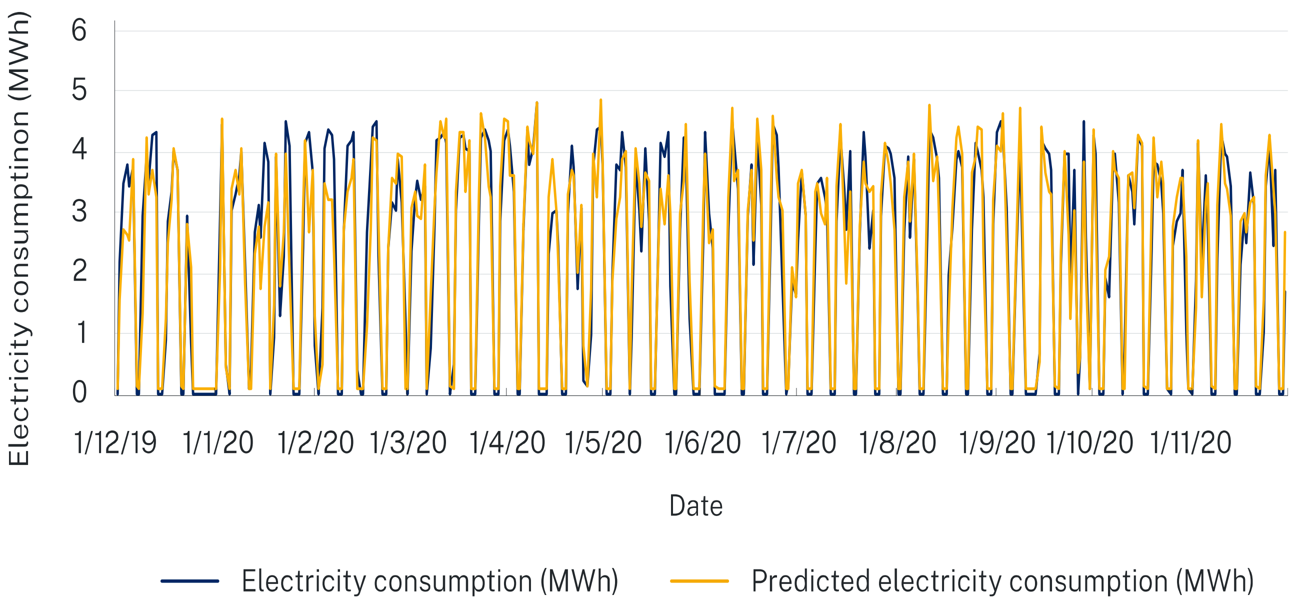
Table A8 Electricity reporting model coefficients, t-statistics and range of independent variables

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

Parameter	Intercept	Square root of kg of dry product
Minimum value	N/A	0
Maximum value	N/a	497.60

Actual verses predicted electricity consumption over the baseline measurement period is shown in figure A7.

Figure A7 Daily actual and predicted electricity consumption in the reporting period



Phase 4: Calculating energy savings using forward creation

The PIAM&V method was used in 2 stages to calculate the energy savings and to forward create Energy Savings Certificates (ESCs) for up to 10 years after the implementation date:

Stage 1: Calculating normal year energy savings (equation 7A.2 of the ESS Rule)

Stage 2: Calculating total energy savings (equation 7A.1 of the ESS Rule).

Stage 1: Calculating normal year energy savings

This stage used equation 7A.2 of the ESS rule to calculate the normal year energy savings. For both gas and electricity calculations, modelled baseline energy consumption data, modelled operating energy consumption data and normal year independent variables and site constants data were used in the computations.

Normal year

The normal year selected was the 2020 calendar year, as it was reflective of the expected typical operation of the site in the future. This facility was unimpacted by COVID-19 due to it being classified as essential service. The range of independent variables in the normal year is highlighted in table A9.

Effective range and effective range adjustment factor (ERAF)

None of the normal year independent variable values were outside the effective range of the 2 energy models. Therefore, there was no need to calculate the ERAF.

Table A9 Range of independent variables in the normal year

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

The effective range of the independent variables for the gas and electricity baseline and operating energy models, and the normal year minimum and maximum values are shown in tables A10 and A11.

Table A10 Effective range for gas models

Parameter	Baseline	Operating	Normal year
Minimum value	0	0	0
Maximum value	238,042	247,606	247,606
Range	238,042	247,606	247,606
Effective range minimum	0	0	-
Effective range maximum	249,944	259,986	-

Table A11 Effective range for electricity models

Parameter	Baseline	Operating	Normal year
Minimum value	0	0	0
Maximum value	487.9	497.6	497.6
Range	487.9	497.6	497.6
Effective range minimum	0	0	-
Effective range maximum	512.3	522.5	-

Interactive energy effects

There were no interactive effects. Changes to gas or electricity consumption within the measurement boundary were not expected to affect energy use outside the boundary.

Calculating normal year electricity savings

Using equation 7A.2 from the ESS rule, the normal year energy savings are calculated as the difference between the energy consumption predicted by the baseline energy model and the operating energy model, where both models use the normal year conditions (independent variables and site constants).

$$Normal\ Year\ Eligible\ Fuel_f Savings\ =$$

$$\sum_t \left(\left(E_{Baseline,f}\left(\tilde{x}_1(t), \tilde{x}_2(t), \dots \tilde{x}_p(t)\right) - E_{Operating,f}\left(\tilde{x}_1(t), \tilde{x}_2(t), \dots \tilde{x}_q(t)\right)\right). ERAF_{ft} \right. \\ \left. + Interactive\ Energy\ Effects_f \right)$$

Figures A8 and A9 show the gas and electricity consumption profiles, respectively. These were predicted by the baseline and operating energy models in the normal year. The results are shown in table A12.

Figure A8 Baseline and operating gas energy adjusted to normal conditions

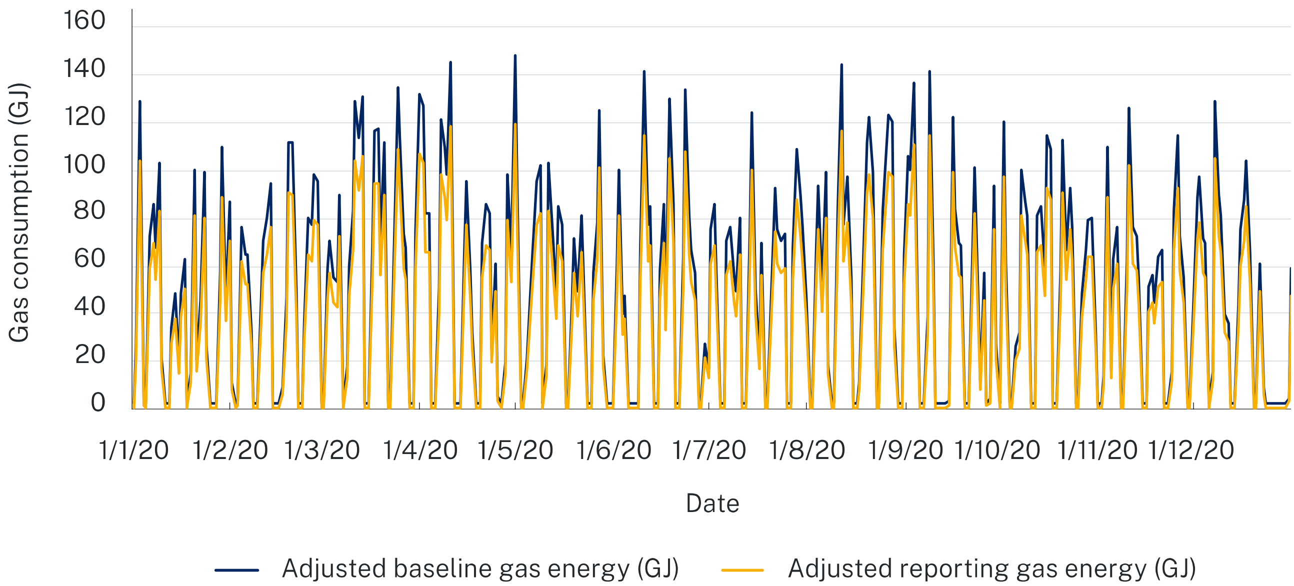


Figure A9 Baseline and operating electricity consumption adjusted to normal conditions

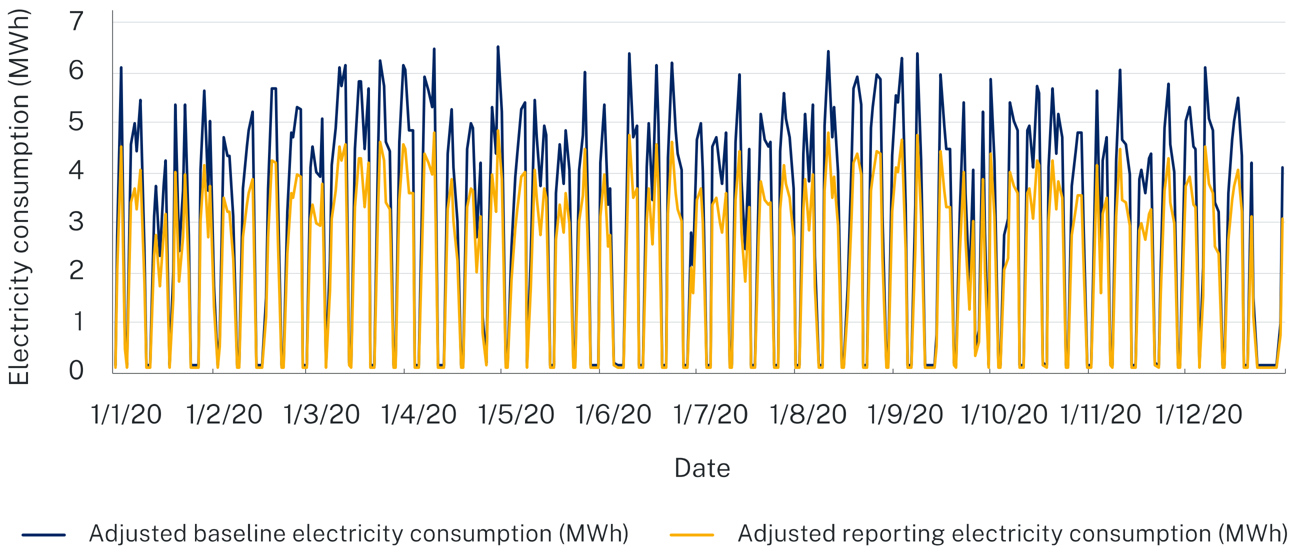


Table A12 Savings determination

Parameter	Gas (GJ)	Electricity (MWh)
Total adjusted baseline energy	18,425	1,131
Total adjusted operating 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 90% confidence level	592	45

Parameter	Gas (GJ)	Electricity (MWh)
Relative precision*	16%	15%

*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.

Stage 2: Calculating total electricity savings

This stage used equation 7A.1 in the ESS rule to calculate the sum of gas and electricity savings for each year in the forward creation period. The savings calculation process accounted for the accuracy factor, the decay factor for each year in the forward creation period (to account for equipment degradation over time) and for any counted energy savings that had already been calculated for the implementation (if any) in each year.

Accuracy factor

For both gas and electricity calculations, the accuracy factor was based on the relative precision of the savings which accounts for the modelling and sub-metering. Sources of error are shown in table A13.

According to the ESS rule, the relative precision is the overall error in the savings at the 90% confidence level as calculated in table A12. Tables A13 and table A14 are used in calculating the relative precision.

Based on table A23 of Schedule A to the ESS rule, an accuracy factor of one was applied.

Table A13 Calculation of standard errors

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

Table A14 Calculation of relative precision

ID	Description	Gas (GJ)	Electricity (MWh)	Formula
A	Total adjusted baseline energy	18,425	1,131	
B	Total adjusted operating 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	
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

Counted energy savings

There were no energy savings for which ESCs were previously created for the implementation. So, the counted energy savings were zero.

Decay factors and persistence model

ESCs will be forward-created for up to 10 years following the implementation. The ESS rule allows for the use of a ‘persistence model’ to estimate the decay of energy savings over the forward creation period.

The persistence model that is part of the PIAM&V Method tool has been used in this example.

The tool is found here: https://www.environment.nsw.gov.au/business/piamv-tool.htm

Where more than one EEM was being implemented, the most conservative decay factors were chosen. In this case, the persistence model for upgrading the burners was used. This falls under 'Drying and evaporation > Drying and evaporation > Upgrade equipment'.

Using the PIAM&V tool, the maximum forward creation period and annual decay factors were determined as shown in table A15 and A16.

Table A15 Parameters selected in the ESS persistence model

Parameter	Value
Equipment type	Drying and evaporation
Category	Drying and evaporation
Subcategory	Upgrade equipment
Postcode	XXXX
Coastal location	Not within 500 m of coast
Equipment use	5 days/week
Water hardness	Moderate: 61-120 mg/L salts
UV exposure	Internal

Table A16 Decay factors

Year after implementation	Decay factor
1	1
2	0.992
3	0.982
4	0.972
5	0.961
6	0.948
7	0.935
8	0.92
9	0.903

Year after implementation	Decay factor
10	0

Calculating and creating ESCs

The energy savings were calculated in accordance with equation 7A.1 of the ESS rule as shown in table A17. Equation 7A.1 is shown below.

$$Eligible\ Fuel_f\ Savings = \sum_i (Normal\ Year\ Eligible\ Fuel_f\ Savings \times Accuracy\ Factor_f \times Decay\ Factor_{fi} - Counted\ Energy\ Savings_{fi})$$

The ESS rule requires that all eligible fuel savings are in MWh. Therefore, total normalised gas savings will need to be converted from GJ into MWh by dividing by a conversion factor of 3.6.

3,717 GJ ÷ 3.6 GJ/MWh = 1,033 MWh

Table A17 Calculation of lifetime savings for the purpose of determining the number of ESCs

Year	Decay factor	Normal year gas savings (MWh)	Normal year electricity savings (MWh)	Accuracy factor	Gas savings (MWh)	Electricity savings (MWh)
1	1	1,033	293	1	1,033	293
2	0.992	1,033	293	1	1,024	291
3	0.982	1,033	293	1	1,014	288
4	0.972	1,033	293	1	1,004	285
5	0.961	1,033	293	1	992	282
6	0.948	1,033	293	1	979	278
7	0.935	1,033	293	1	965	274
8	0.92	1,033	293	1	950	270
9	0.903	1,033	293	1	932	265

Year	Decay factor	Normal year gas savings (MWh)	Normal year electricity savings (MWh)	Accuracy factor	Gas savings (MWh)	Electricity savings (MWh)
10	0	1,033	293	1	0	0

Using table A17, the lifetime gas and electricity savings are therefore calculated to be 8,893 MWh and 2,524 MWh, respectively.

Using the energy savings calculated for equipment lifetime (9 years), the number of ESCs can be calculated using the following formula:

$$\sum_{implementations} Electricity\ Savings \times Regional\ Network\ Factor \times Electricity\ Certificate\ Conversion\ Factor + Gas\ Savings \times Gas\ Certificate\ Conversion\ Factor$$

Using an electricity certificate conversion factor of 1.06 and a gas certificate conversion factor of 0.39[3], the total number of ESCs created by the project was 6,143.

According to the ESS rule, the date that the energy savings are taken to occur is the last day of the operating measurement period.

At a certificate price of $30, the ESCs were worth $184,298. Assuming a brokerage and registration charge of $5, then the value of the ESCs to the food manufacturer was $153,582.

Based on the total energy savings calculations, the financial value of the reduced electricity costs was worth $504,722 and the reduced gas costs was worth $342,555 (assuming an electricity tariff of $0.20/kWh and a gas tariff of approximately $10.70/GJ). This was over 5 times greater than the value of the ESCs to the food manufacturer.

[3] The gas certificate conversion factor applicable at the time.

Appendix B

Model residuals

Generally, analysis of the difference between the actual and the predicted energy consumption from a model - or 'residuals' - is Important to validate regression-based models.

If energy consumption pattern change, the effects can be seen in the residuals. When plotted against actual energy consumption, uncorrelated residuals from a non-biased model will be randomly skewed around the x-axis (y = 0) and will sum to zero. Figures A10 - A13 show the residual plots for gas and electricity consumption over the baseline and operating periods.

Figure A10 Baseline period – standardised residuals versus gas consumption (GJ)

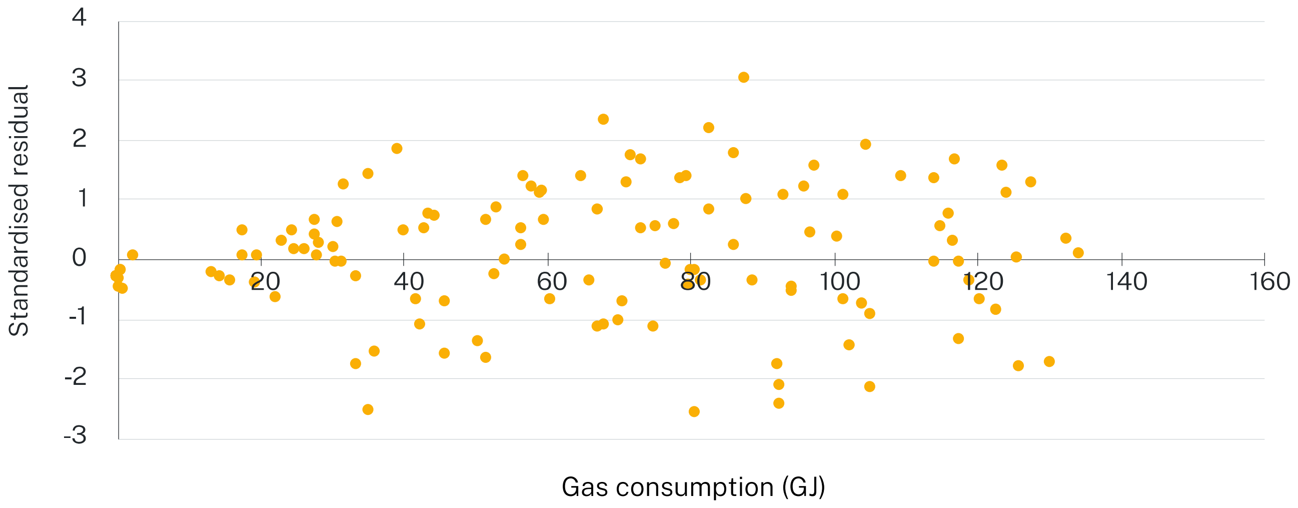


Figure A11 Baseline period – standardised residuals versus electricity consumption (MWh)

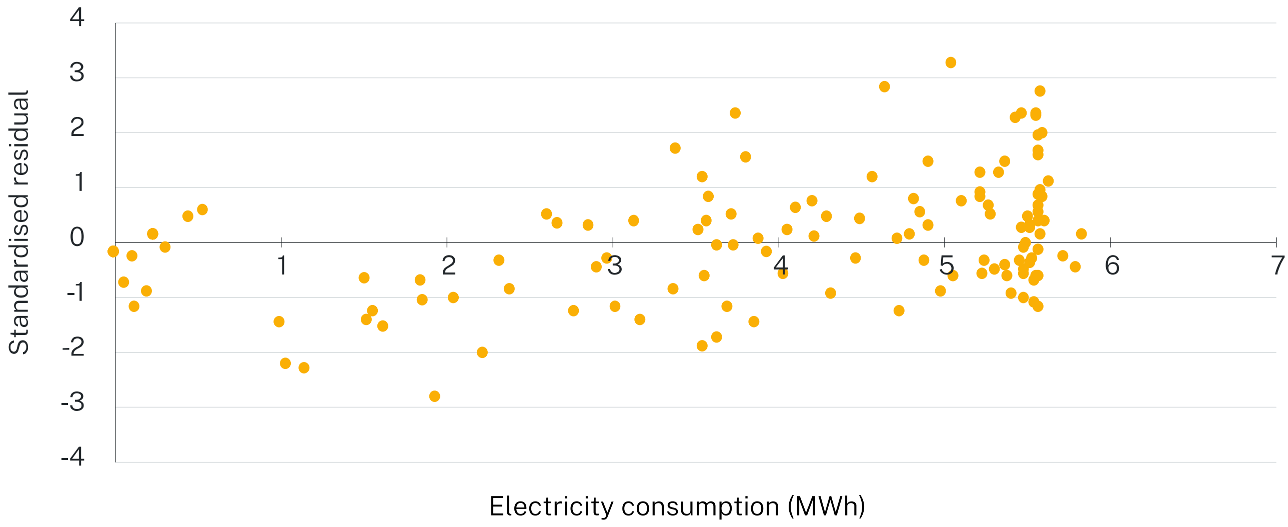


Figure A12 Operating period – standardised residuals versus gas consumption (GJ)

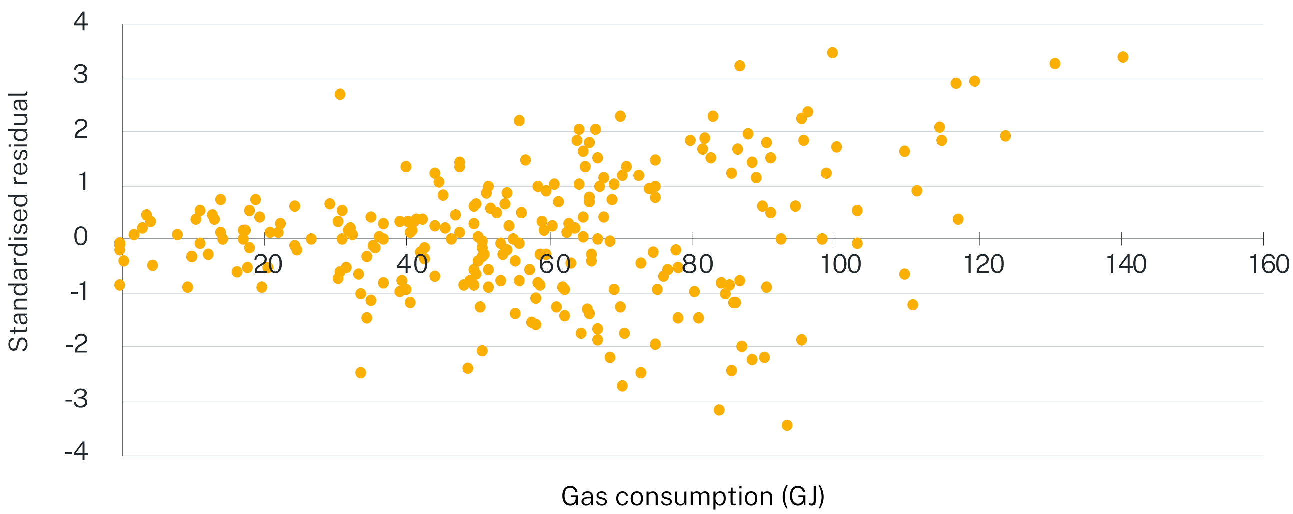
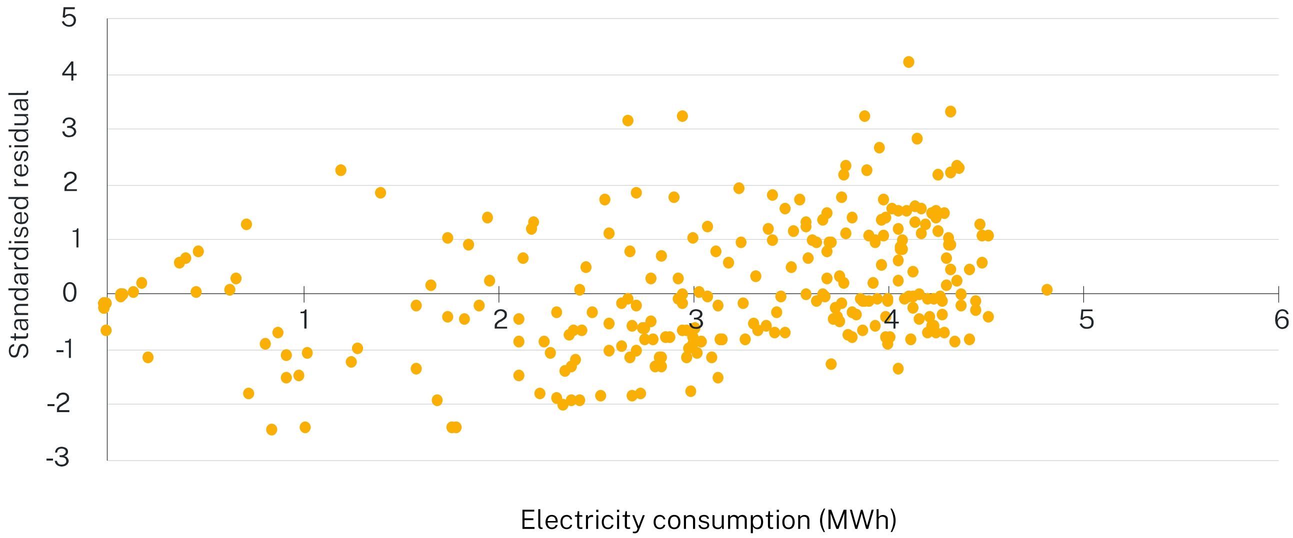


Figure A13 Operating period – standardised residuals versus electricity consumption (MWh)



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