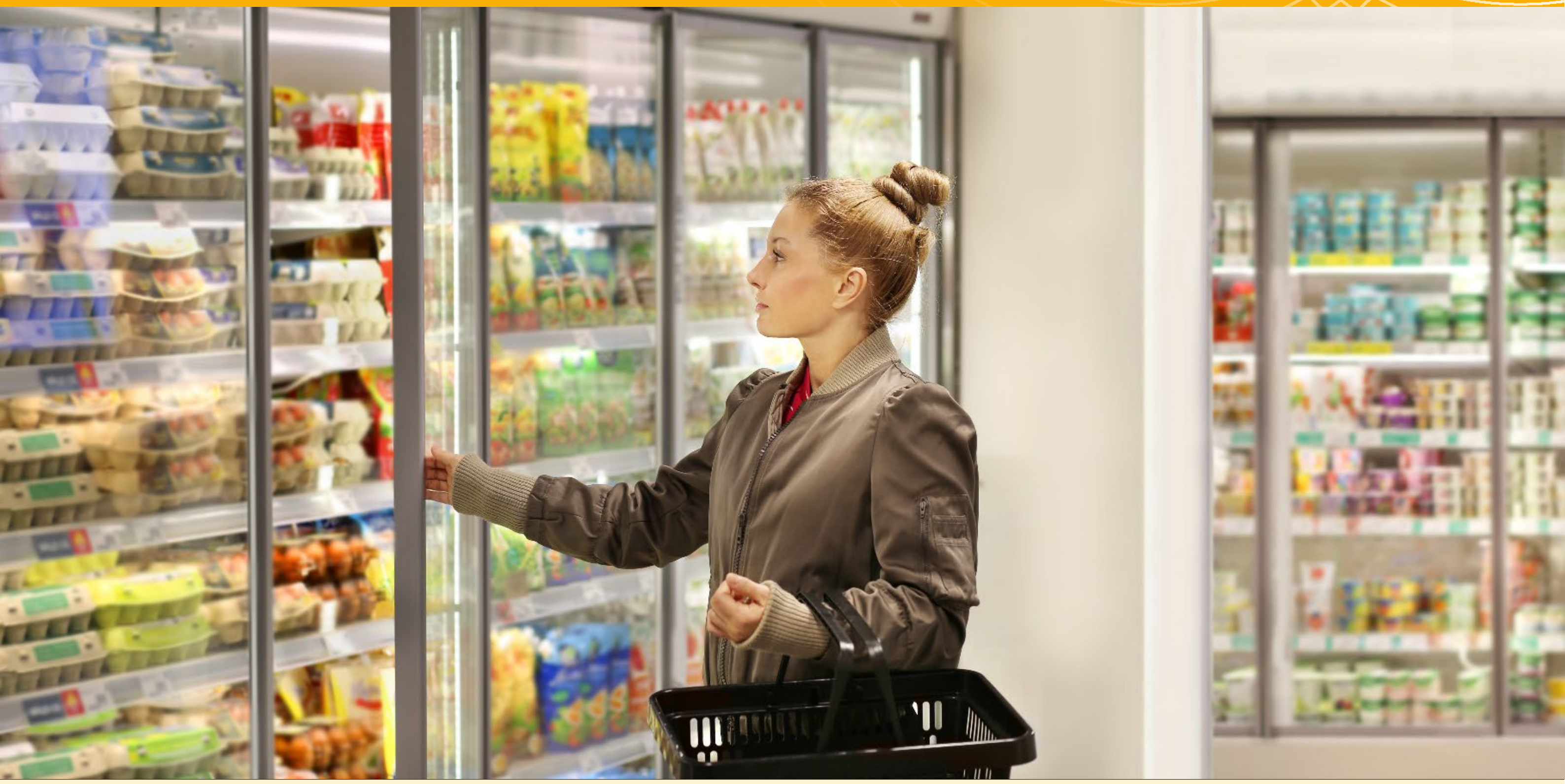
The Department of Climate Change, Energy, the Environment and Water

Measurement and verification demonstration project



Supermarket: 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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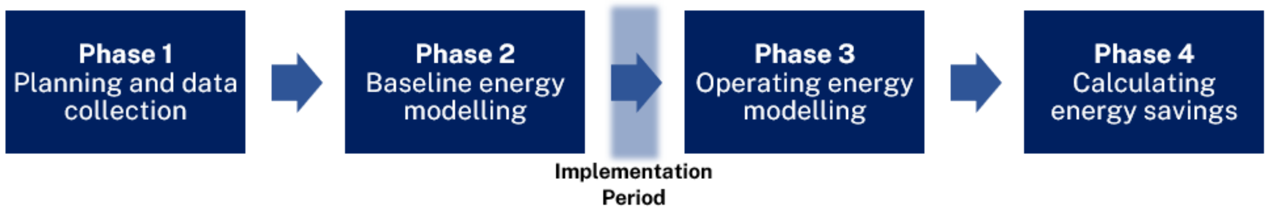
Appendix A

Calculating energy savings under the Energy Savings Scheme

Under the Energy Savings Scheme (ESS), energy savings are calculated using the Project heading Impact Assessment with Measurement and Verification (PIAM&V) method. This method uses M&V principles to compare modelled energy consumption before an implementation 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)

The equipment used to achieve the energy savings waere a voltage optimisation (VO) unit installed on the power supply and variable speed drives (VSDs) fitted to the refrigeration compressors.

Measurement boundary

The measurement boundary chosen was the whole-site electricity consumption, measured using the utility meter – International Performance Measurement and Verification Protocol (IPMVP) Option C. This was because all electricity supplied to the site flowed through the

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

voltage optimisation equipment. An alternative would be to isolate the refrigeration savings from the VO unit savings by using 2 boundaries. This would enable the economic savings from each upgrade to be determined. This alternative was not chosen because the overall savings was considered sufficient.

Independent variables and site constants

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

- average daily temperature, taken as the average of the minimum and maximum temperatures in degrees Celsius
- a binary variable for whether the day of week was Sunday
- a binary variable for whether the site was open or closed.

The excluded independent variables were the binary variables for Monday to Saturday as they did not have acceptable t-statistics.

The selected site constants were:

- site operational hours
- site floor area
- counts of existing electrical equipment.

Data for the site constants collected was as follows:

- Site operational hours
  - Monday to Friday: 7 am to 10 pm
  - Saturday and Sunday: 8 am to 10 pm
- HVAC operating hours
  - Monday to Saturday: 5:30 am to 9:30 pm
  - Sunday: 6 am to 9 pm
- Site floor area: 610 m^2
  - Equipment counts
  - Number of internal 40 W (LED) troffer lights: 150
  - Number of external 100 W (LED) flood lights: 6
  - Number of toilet exhaust fans: 2

  - Number of packaged air conditioning units: 3
  - Number of cool room evaporator units: 2
  - Number of freezer room evaporator units: 2
  - Number of refrigeration compressors: 10
  - Number of air-cooled condensers: 6
  - Number of freezer cabinets: 10
  - Number of refrigerated cabinets: 12

Measurement period and operating cycle

Since the on-site energy use varies with the weather, a 12-month operating cycle was chosen which allowed for summer and winter seasonal energy use to be included.

Measurement procedures

- Electricity interval data was collected from the site utility meter and summarised into daily data. Since utility meter data was used, there were no calibration requirements.
- Independent variables data included:
  - Weather data, which was collected from the nearest Bureau of Meteorology weather station.
  - data provided by the energy user including:
    - day of week with each day as a binary variable
    - days when the site was closed (Christmas Day, Good Friday, Easter Sunday) as a binary variable.
- Data for energy consumption and the independent variables were collected daily for a period of 12 months in the baseline and operating measurement periods. Site constant values were verified quarterly.
- The chosen measurement periods were reasonable because 12 months would capture the seasonal variation in energy use. They also included time periods during which independent variables may reasonably be expected to result in increasing energy consumption (summer and winter).

Engaging an M&V professional

A third-party M&V professional was engaged to review the M&V plan after the baseline energy model was developed to ensure that the M&V processes completed were adequate. The review is discussed in more detail below.

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 was 12 months to capture seasonal variation in electricity use. This choice was made to ensure the inclusion of a complete operating cycle of the site electricity consumption.

The formula below was used to determine the relationship between the dependent variable (electricity consumption) and the independent variables:

Daily electricity consumption (kWh) = 1919.7 + 31.24 x (Average Temperature) – 86.56 x (is Sunday) – 744.53 x (is closed)

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

Table A1 Baseline model statistical test results

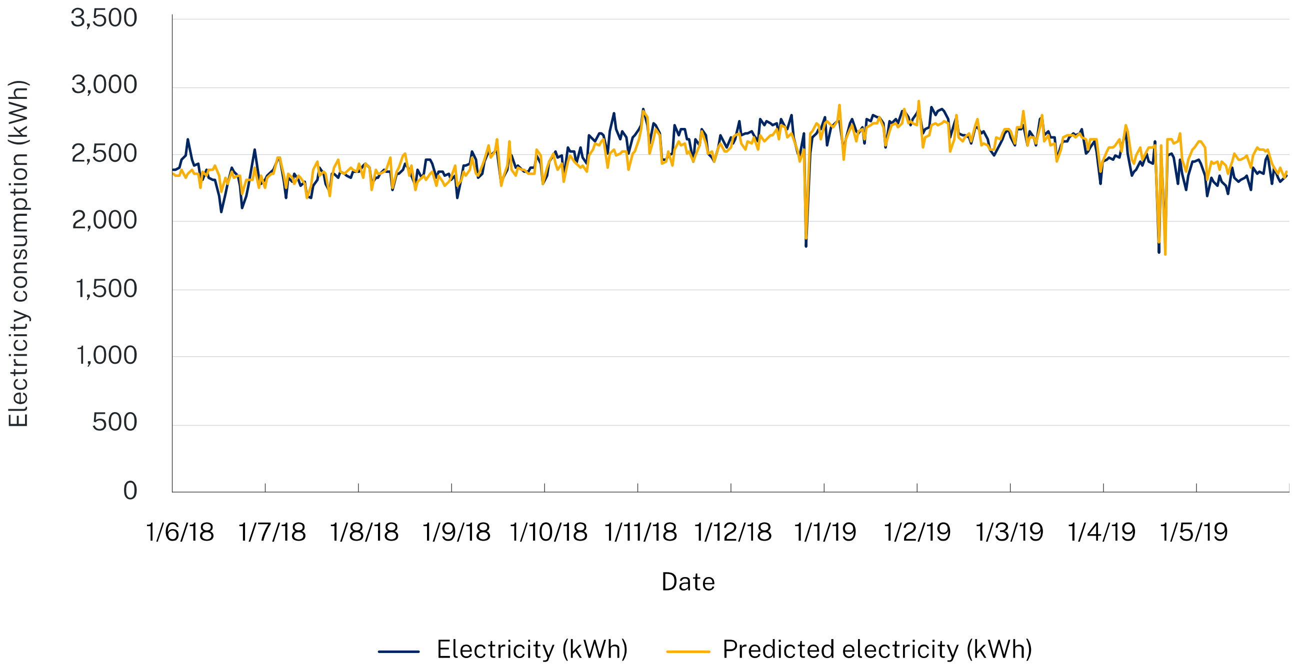
Parameter	Value	ESS requirement	Acceptable?
Observations per independent variable	121.7	$\geq$ 6	Yes
Adjusted R^2	0.78	$\geq$ 0.5	Yes
CV_{RMSE}	0.033	< 0.25	Yes

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

Parameter	Intercept	Average temperature (°C)	Sunday	Site closed
Coefficient	1919.7	31.24	-86.56	-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

Figure A2 shows the electricity consumption predicted by the baseline energy model as compared to the actual electricity consumption.

Figure A2 Electricity consumption predicted by baseline energy model compared to actual electricity consumption



No non-routine events were identified during the baseline measurement period, so 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.

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 implementation of the 2 upgrades took place over a period of 2 weeks. The parameters identified in Phase 1 were used to develop a daily operating energy model.

A 12 month operating measurement period was selected to take into consideration the seasonal variations (Summer and winter) and to ensure the inclusion of a complete operating cycle of the site's electricity consumption.

The formula below was used to determine the relationship between the dependent variable (electricity consumption) and the independent variables of choice.

> Daily electricity consumption (kWh) = 1560.6 + 38.44 x Average Temperature – 71.47 x (is Sunday) – 365.91 x (is closed)

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

Table A3 operating energy model statistical test results

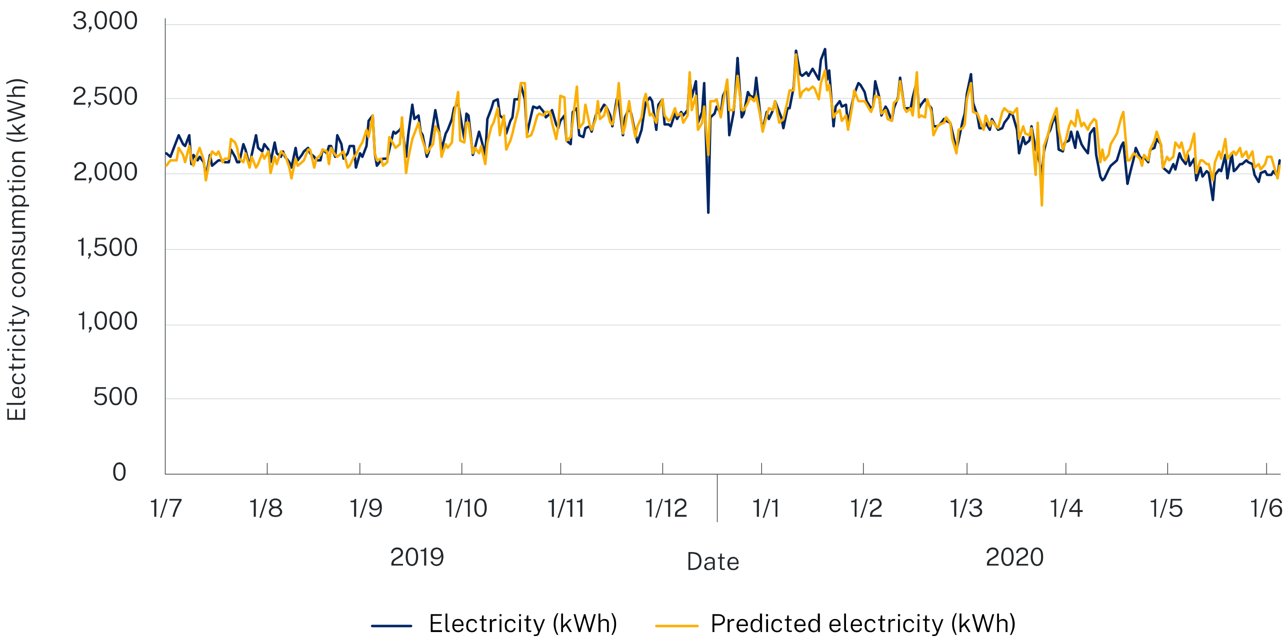
Parameter	Value	ESS requirement	Acceptable?
Observations per independent variable	122	≥ 6	Yes
Adjusted R^2	0.79	≥ 0.5	Yes
CV_{RMSE}	0.038	< 0.25	Yes

Table A4 operating model coefficients, t-statistic, and range of independent variables of choice

Parameter	Intercept	Average temperature	Sunday	Site closed
Coefficient	1560.6	38.44	-71.47	-365.91
t-statistic	74	36	-5.6	-7.3
t-statistic acceptable? (> |2|)	N/A	Yes	Yes	Yes
Minimum value		11.55	0	0
Maximum value	N/A	32.2	1	1

Figure A3 shows the electricity consumption predicted by the operating energy model as compared to the actual electricity consumption.

Figure A3 Electricity consumption predicted by operating energy model compared to actual electricity consumption



No non-routine events were identified during the operating measurement period. Therefore, no non-routine adjustments were required to the operating energy model.

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 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 electricity savings. The modelled baseline energy consumption data, the modelled operating energy consumption data and the normal year independent variables and site constants data was used.

- Normal year: The normal year selected was the 2019 calendar year since it was representative of the likely future operation of the site. The range of independent variables in the normal year is highlighted in table A5.
- Effective range and effective range adjustment factor (ERAF): Values of the site constants during the normal year did not change from their values outlined in Phase 1.

Table A5 Range of independent variables in the normal year

Parameter	Minimum value	Maximum value
Average temperature (^{O}C)	10.8	31.2
is Sunday (binary variable)	0	1
is closed (binary variable)	0	1

The effective range of the average temperature for both the baseline and operating energy models and the normal year minimum and maximum values are shown in table A6.

For the 2 binary independent variables, the range of variables was identical in the baseline and operating energy models and the normal year. There were zero data exclusions in the normal-year electricity savings calculation.

Table A6 Effective range of average temperature

Parameter	Baseline	Operating	Normal year
Minimum value	10.85	11.55	10.85
Maximum value	31.20	32.2	31.20
Range	20.35	20.65	20.35
Effective range minimum	9.83	10.52	-
Effective range maximum	32.22	33.23	-

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 Effective Range Adjustment Factor (ERAF).

- Interactive energy effects: Since the measurement boundary was the site utility meter, there were no interactive energy effects for electricity. While the supermarket uses gas, the EEMs had no impact on gas consumption, so there were no interactive effects for gas as well.
- Calculating normal year electricity savings: Using equation 7A.2 from the ESS rule, the normal year savings are calculated as the difference between the electricity 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).

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

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

Figure A4 shows the electricity consumption profiles predicted by the baseline and the operating energy models in the normal year. The results are shown in table A7.

Figure A4 Baseline and reporting energy adjusted to 'normal' conditions

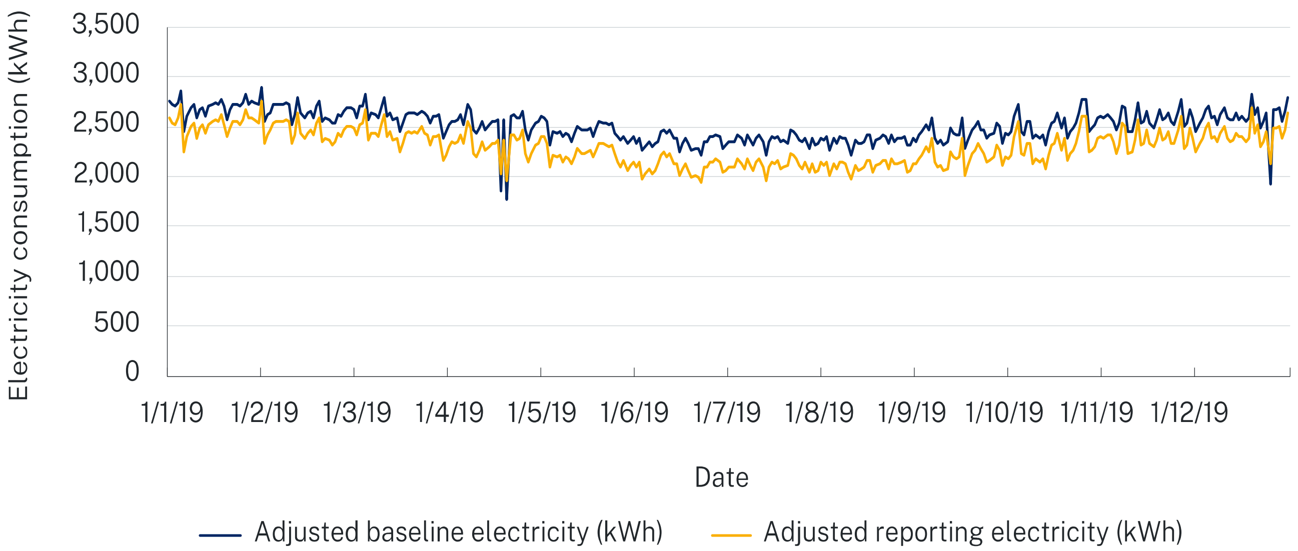


Table A7 Savings determination

Parameter	Value (kWh)
Total adjusted baseline energy	916,702
Total adjusted reporting energy	838,921
Total normalised savings	77,782
Savings as a percent of the adjusted baseline	8.5%

Stage 2: Calculating total electricity savings

This stage used equation 7A.1 in the ESS rule to calculate the sum of 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 in each year.

- Accuracy factor: The accuracy factor was based on the relative precision of the calculated electricity savings which accounts for modelling errors. Since the utility meter was used, there were no metering errors. According to the ESS rule, the relative precision is the overall error in the savings at the 90% confidence as calculated in Table A8. Based on table A23 of schedule A of the ESS rule, an accuracy factor of one applied.

Table A8 Calculation of relative precision

Parameter	Baseline	Operating
SE_y: Regression model standard error (kWh)	83.66	85.85
SE_{tot}: Total standard error = $SE_y \times \sqrt{N}$ (kWh)	1,598	1,640
N: Number of observations in the normal year		365
SE_{s-tot}: Total standard error of savings (kWh) = $\sqrt{SE_{s-tot}(\mathrm{BL})^2 + \mathrm{SE}_{s-tot}(\mathrm{OP})^2}$		2,290
Degrees of freedom: $(N - 1 - Number\ of\ independent\ variables) = 365 - 1 - 3$		361
t: t-value @ 90% confidence level		1.649
$SE_{s(90\%)}$: Standard error of savings at 90% confidence level (kWh) = SE_s x t		3,777
Electricity savings (kWh)		77,782
Relative precision of electricity savings (%) = $SE_{s(90\%)} \div Savings$		4.9%
Accuracy factor (Based on table A23 in the ESS rule)		1

- Counted energy savings:

There have been no previous energy savings implementation for which ESCs were created. Therefore, 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 (version 2.2) was used in this example. The tool is found here: https://www.environment.nsw.gov.au/business/piamv-tool.htm. Where more than one EEM is being implemented, the more conservative decay factors should be chosen. In this case the persistence model for the VSDs and the VO unit gave the same decay factors.

Using the PIAM&V tool, the maximum forward creation period and annual decay factors were then determined as shown in tables A9 and A10.

Table A9 Parameters selected in the ESS persistence model

Parameter	Value
Equipment type	Refrigeration and cooling
Category	Control system
Subcategory	Upgrade unit controls
Postcode	XXXX
Coastal location	Not within 500m of coast
Equipment usage	N/A
Water hardness	N/A
UV exposure	N/A

Table A10 Decay factors

Year after implementation	Decay factor
1	1
2	0.99
3	0.99
4	0.98
5	0.97
6	0.96
7	0.96
8	0.95

- Calculating and creating ESCs:

The energy savings were calculated in accordance with Equation 7A.1 of the ESS rule as shown in table A12. Equation 7A.1 is shown below.

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

Table A11 Calculation of lifetime savings for the purpose of determining the number of ESCs

Year	Decay factor	Normal year savings (MWh)	Accuracy factor	Energy savings (MWh)
1	1	77.782	1	77.782
2	0.99	77.782	1	77.004
3	0.99	77.782	1	77.004
4	0.98	77.782	1	76.226
5	0.97	77.782	1	75.448
6	0.96	77.782	1	74.670
7	0.96	77.782	1	74.670
8	0.95	77.782	1	73.893

Using table A11, the lifetime energy savings are therefore calculated to be 606.70 MWh.

Using the energy savings calculated for equipment lifetime (8 years), the number of ESCs can be calculated using the following formula:

$$\sum_{implementations} Total\ Electricity\ Savings\ (MWh) \times Regional\ Network\ Factor \times Electricity\ Certificate\ Conversion\ Factor$$

Using a regional network factor of 1 and an electricity certificate conversion factor of 1.06, the number of ESCs created by the project was 643.

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 $19,290. Assuming a brokerage and registration charge of $5, then the value of the ESCs to the supermarket was $16,075.

Based on the electricity savings calculation, the financial value of the reduced electricity costs was worth $121,339 (assuming an electricity tariff of $0.20/kWh). This was approximately 7.5 times greater than the value of the ESCs to the supermarket.

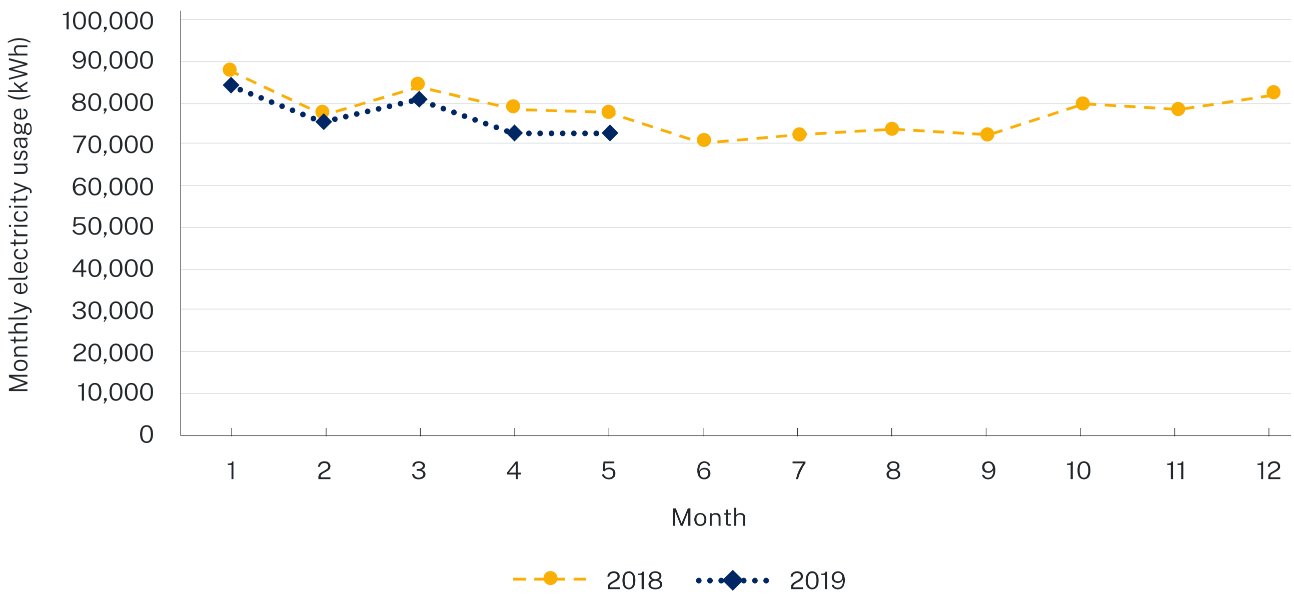
Appendix B

Accuracy of the selected baseline measurement period

The available baseline data, from January 2018 to May 2019, showed that electricity use at the end of the baseline period (first 5 months of 2019) was lower than the energy use during the same months at the start of the baseline period. This is shown in figure A5.

There was no known explanation for this decrease.

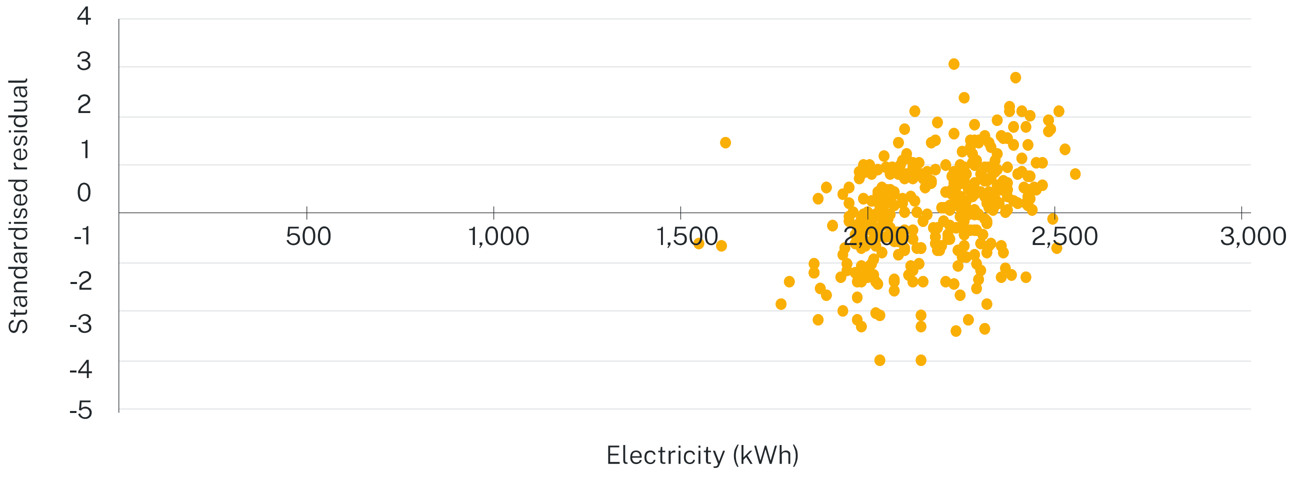
Figure A5 All available baseline data, illustrating a declining baseline



The baseline period selected was the 12-month period with the lowest total energy use, i.e. from 1 June 2018 to 31 May 2019. This was based on the IPMVP principle of being 'conservative'.

While this produced acceptable regression statistics, a plot of the residuals of the model showed that there was some pattern to the residuals. This is shown in figure A6. Ideally the residuals plot should have no pattern.

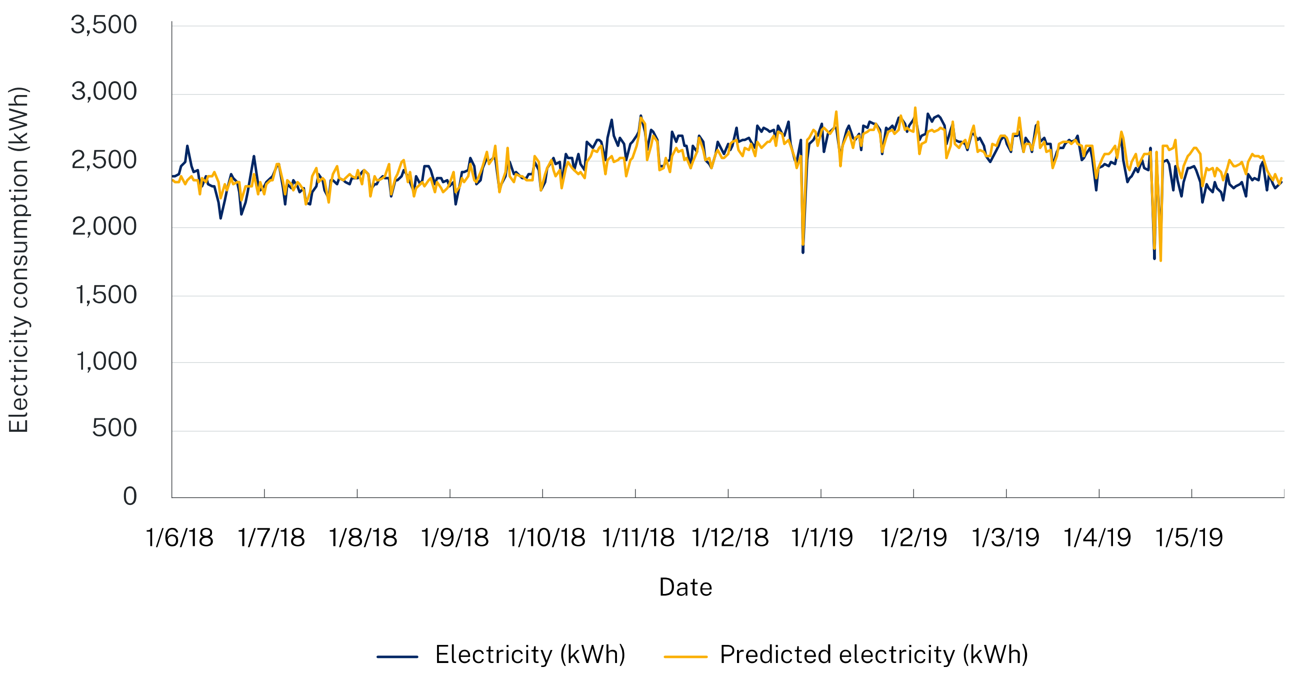
Figure A6 Residuals plot when June 2018 to May 2019 is the baseline year



The residuals pattern is an indication that the baseline model was underestimating the electricity consumption during the days when consumption was high and overestimating consumption on days when energy consumption was lower.

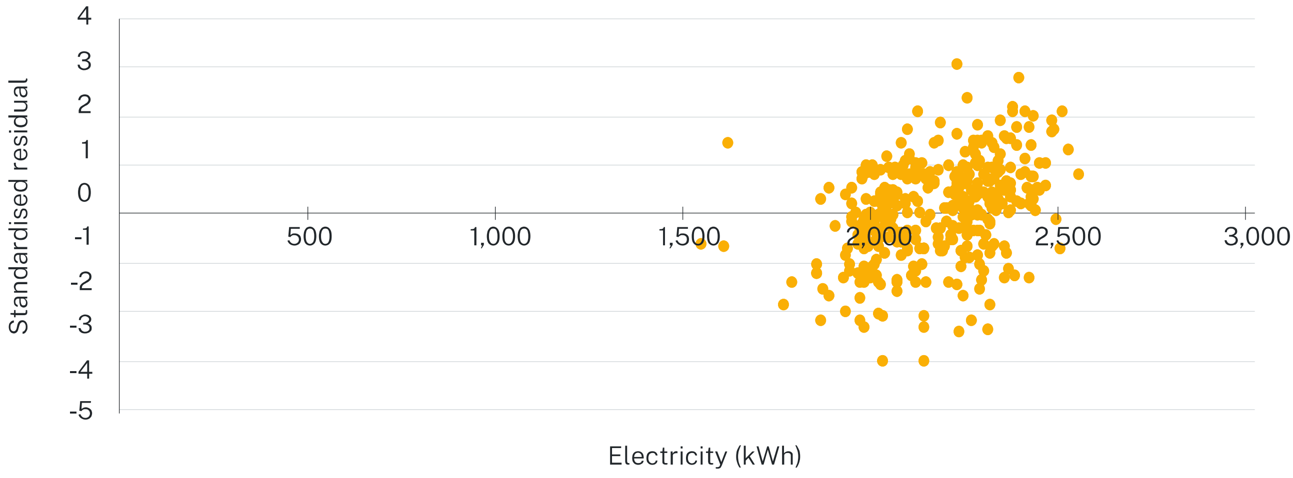
Figure A7 shows that at the end of the baseline period, covering the first months of 2019, the baseline model is overestimating consumption.

Figure A7 Actual and predicted baseline electricity use, when June 2018 to May 2019 is the baseline year



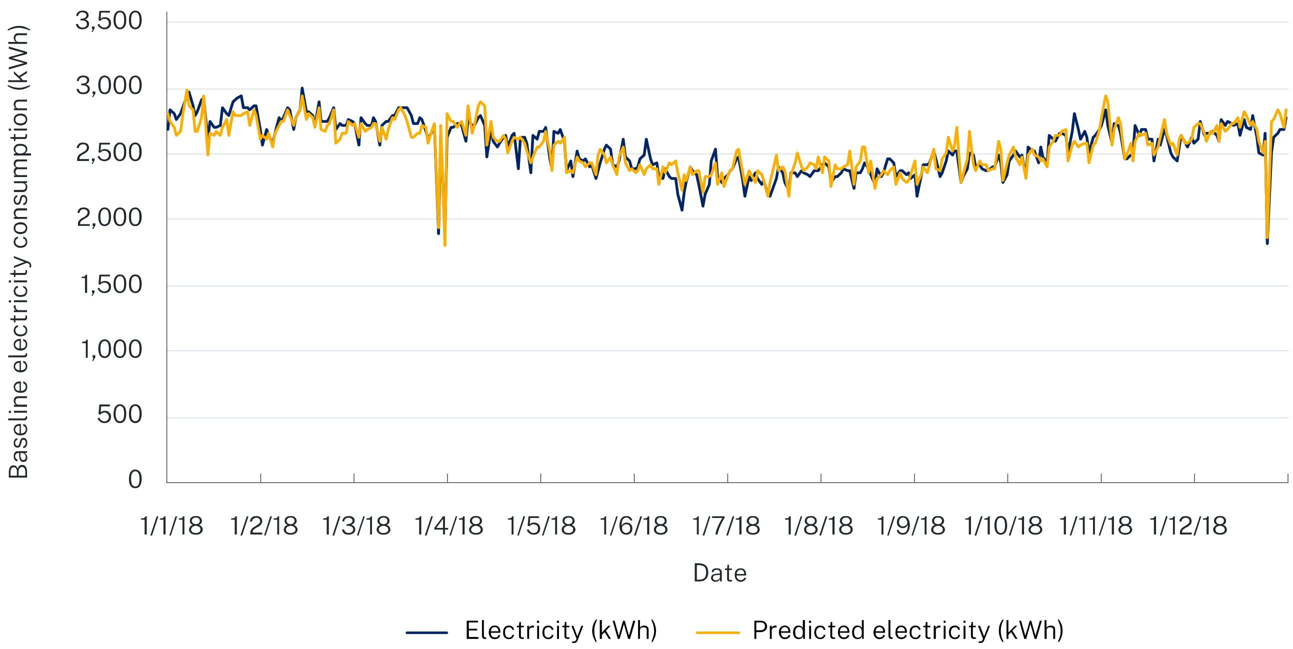
Selecting calendar year 2018 as the baseline resulted in a more random residuals plot as shown in figure A8. While there is still some pattern, it is weaker than when the baseline ran from 1 June 2018 to 31 May 2019.

Figure A8 Residuals plot when 2018 calendar year is the baseline year



The accuracy of the model is further illustrated in figure A9 which shows the actual versus predicted based on the regression model.

Figure A9 Actual and predicted baseline electricity use, when 2018 is the baseline year



The standard regression tests are also slightly better when the 2018 calendar year was chosen as the baseline compared to when the baseline ran from 1 June 2018 to 31 May 2019.

Table A12 Regression statistics for different baseline years

Baseline period	1 June 2018 to 31 May 2019	1 January 2018 to 31 December 2019
Observations per independent variable	121. 7	121. 7
Expected values error	0.000%	0.000%
Adjusted R^2	0.78	0.85
CV_{RMSE}	0.033	0.030

The normalised savings when choosing 2018 as the baseline year are 99,021 kWh versus 77,782 kWh when the baseline year is 1 June 2018 to 31 May 2019. If 2018 is chosen as the baseline year, the savings are 27% higher.

Following the IPMVP principle of being ‘conservative’, 1 June 2019 to 31 May 2019 was chosen as the baseline. While the selected baseline model is not as accurate as when 2018 calendar year was selected, it still has an acceptable level of accuracy.

For more information on the Energy Security Safeguard

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