Measurement & Verification Plan

Customer: *GMG*

Site: *Carina Library*

Date: *13 August 2021*

Document Control

Version	Change descriptions	Prepared By	Reviewed By	Date published
1	Issued	Kane Ivers Kane@CatalystCollective.com.au	Bruce Rowse 8020 Green	13/8/2021

1 Facility and Project Overview

This document is designed to outline the measurement and verification process to confirm if any measurable savings can be shown through the application THERMAL-XR (TXR) to the heat exchange surfaces on the Carina library HVAC system. Catalyst collective was contracted to assist with measurement and verification of this process after the application of TXR had been completed. This report is designed to confirm the process that was followed and to confirm, were possible, alignment to IPMVP guidelines.

Carina library is located in on the corner of Mayfield Rd and Nyrang St, Carina, Brisbane Queensland.

The site is operational as per the following opening hours

- Monday: 10am-6pm
- Tuesday: 10am-6pm
- Wednesday: closed
- Thursday: closed
- Friday: 10am-6pm
- Saturday: 9am-4pm
- Sunday: closed

*Covid lockdowns ~ ~ January 8-11 and March 29-31

The site has a temperzone OPA550RKTBG01-P HVAC system on the side of the building. See appendix technical specfications

Figure 1- Photo of installation of the HVAC system

Figure 2 – Location information

Figure 3 – Name Plat of HVAC

1.1 Thermal XR

TXR is a water-based acrylic resin impregnated with thermally conductive GMG Graphene applied by high-pressure spray gun. The coating is UV resistant, with a DFT of no more than 15 microns, flexible and highly resistant to aggressive environments. The process coats and protects damaged heat exchange surfaces while rebuilding the lost corroded thermal conductivity—this results in an improvement in efficiency and a reduction in power consumption

1.1.1 Application Process

Before the TXR is applied, the coil must be cleaned and dried using the TXR Process. The TXR coating must be applied with at least three quality passes in both the horizontal and vertical directions across the coil. This will allow the coating to contact the collar and any previously damaged heat exchange surfaces. Compressed air pressure should be between 40-60 PSI using a tight spray pattern at no more than 100mm from surface.

2 ECM Intent

The hypothesis being tested was that the TXR application would yield appreciable energy savings on the HVAC system. It is proposed that through improving the heat conductivity of the HVAC coil the energy efficiency of the unit shall be increased by up to %50.

To show this, we will measure the amount of electrical energy used during the baseline period by the HVAC system. A multivariable regression model will be built using weather data from a near by weather station. If a suitable model can be developed, this will be used to estimate expected energy post application of the TXR coating. This is to be compared against actual energy use and this difference will be considered the savings.

3 Selected IPMVP Option and Measurement Boundary

Option B will be used to evaluate savings. A power meter is to be retrofitted to the HVAC system to measure the total energy used. The total energy used by the system is expected to be affected by heat load and occupancy of the building, weather such as temperature, wind and rain.

4 Baseline: Period, Usage and Conditions

Data for the baseline period was collected from 22.01.2021 through to when the TXR service was completed on 11.03.2021.

4.1 Identification of the baseline period

The available baseline period for this project is 55 days. As this plan is being developed after the fact, the IPMVP guideline of 1 year of baseline data could not be gathered. An identified concern with this approach is the change of season between baseline period and reporting period. Analysis of how the shortened baseline period effects the accuracy of prediction is outlined in the M&V report.

4.2 Baseline Utility Consumption and Demand Data

The dependant variable in this case is the total energy used by the HVAC system. This was measured via a true power meter connected on the HVAC system electrical incomer. The unit is connected to measure current and voltage from each phase of the HVAC system. Further details on the metering can be found in section 6.2

4.3 Utility Influencing Variable Data

Local weather data is the primary utility influencing data is to be recorded. Weather data to be used will be sourced from weather underground website. The weather station IBRISB1111 is located approximately 500m from the carina library

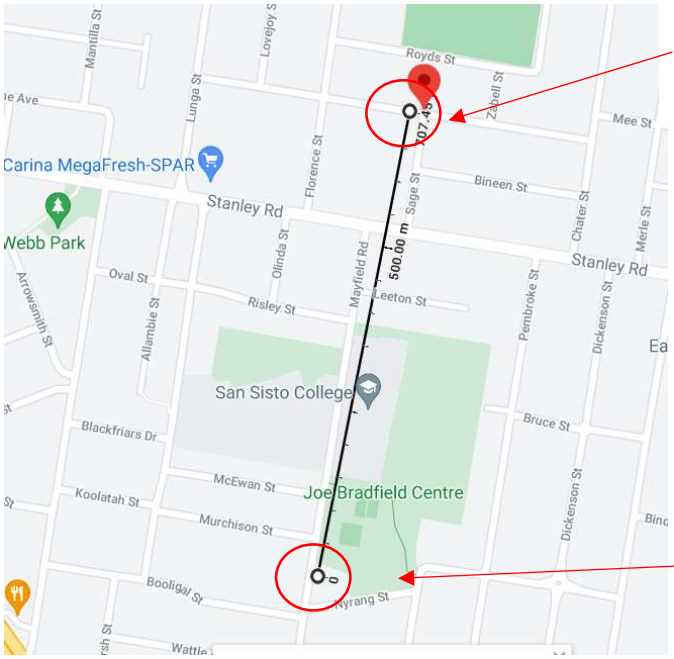


Figure 4 – Location of weather station

https://www.wunderground.com/dashboard/pws/IBRISB1111/table/2021-01-21/2021-01-21/monthly

This weather station records a variety of weather data. Weather data is recorded at a maximum frequency of 5 min samples. It is also averaged and reported daily on the website. Both frequency's will be used in the analysis Primary variable to be considered are

- Daily average temperature (Averaged from the weather underground website)
- Rain fall during opening hours (Calculated using 5 min sample data)
- Average Wind-Speed during opening hours (Calculated using 5 min sample data)

As the base line measurement does not cover any cooler weather, using cooling degree days and heating degree days was not required. Modelling was completed using average temperature

During the model validation phase, it was determined that a suitable model using rain fall during opening hours and average wind speed during opening hours could not be developed.

Various models where trailed. In the end a model using average temperature and digital variable indicating which day of the week the energy was recorded. The results of this analysis are discussed further in the M&V report

4.4 Operating Conditions

During this period the standard opening hours. Covid19 lock down period in Brisbane were between and as such do not affect the baseline measurements January 8-11 and March 29-31

Library opening hours

- Monday: 10am-6pm
- Tuesday: 10am-6pm
- Wednesday: closed
- Thursday: closed
- Friday: 10am-6pm

- Saturday: 9am-4pm
- Sunday: closed

No maintenance outages were recorded during either the baseline or reporting period

A digital variable will be generated using operating hours to indicate if the library was open or not. This will be used as a measure of occupancy. It is expected that operating hours will also affect HVAC load due to the opening and closing of doors as people enter and exit the facility.

5 Reporting Period

Data for the baseline period was collected from 11.03.2021 when the TXR service was completed through to 30.04.2021. The energy is evaluated daily by comparing actual energy used with estimated energy used from the multivariable regression model. Savings are to be reported as average % savings over the reporting period

5.1 Basis for Adjustment

As noted above one concern is seasonal change between baseline period and reporting period. The HVAC system is a reverse cycle unit and as such has a heating cycle. There were no days during the baseline period that were cool enough to require this. As such days where heat in required can-not be modelled. To adjust for this is proposed that days with outside of the range of average temperature from the baseline period are to be excluded from the analysis of the reporting period.

6 Calculation Methodology and Analysis Procedure

6.1 Energy Prices

Savings are to be reported as a percentage of energy used vs predicted energy usage. As such, energy prices are not applicable.

6.2 Electrical Meter

The Seam SS9901 / WEM 3080T electrical meter was used to measure total energy used in the application. Data sheet is attached as appendix C

6.2.1 Electrical Information

The optional 150A current transformers were used in this application

Below is a link to the iammeter interface for this specific meter. This will provide overview information only

https://www.iammeter.com/home/share/63ef77f0823e4e6abd8db3d64215762b

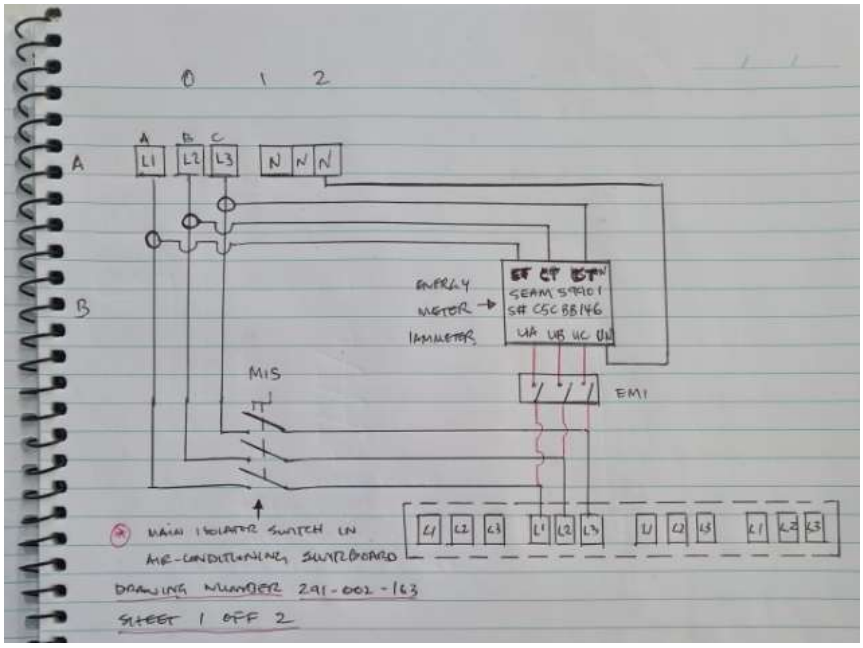


Figure 5 – Schematic of connection for energy data logger

6.3 Monitoring Responsibilities

Connection of the energy data logger and validation of the installation is the responsibility of GMG. Access to the iammeter website has been provided to catalyst collective who is responsible for collecting data from the website for the purpose of modelling and validation.

6.4 Expected Accuracy

The accuracy is expected to be +/- 1% inline with the accuracy of the data logger. IEC62053-21 accuracy index class 1

7 Budget

As this report is being generated after the fact budget is not applicable.

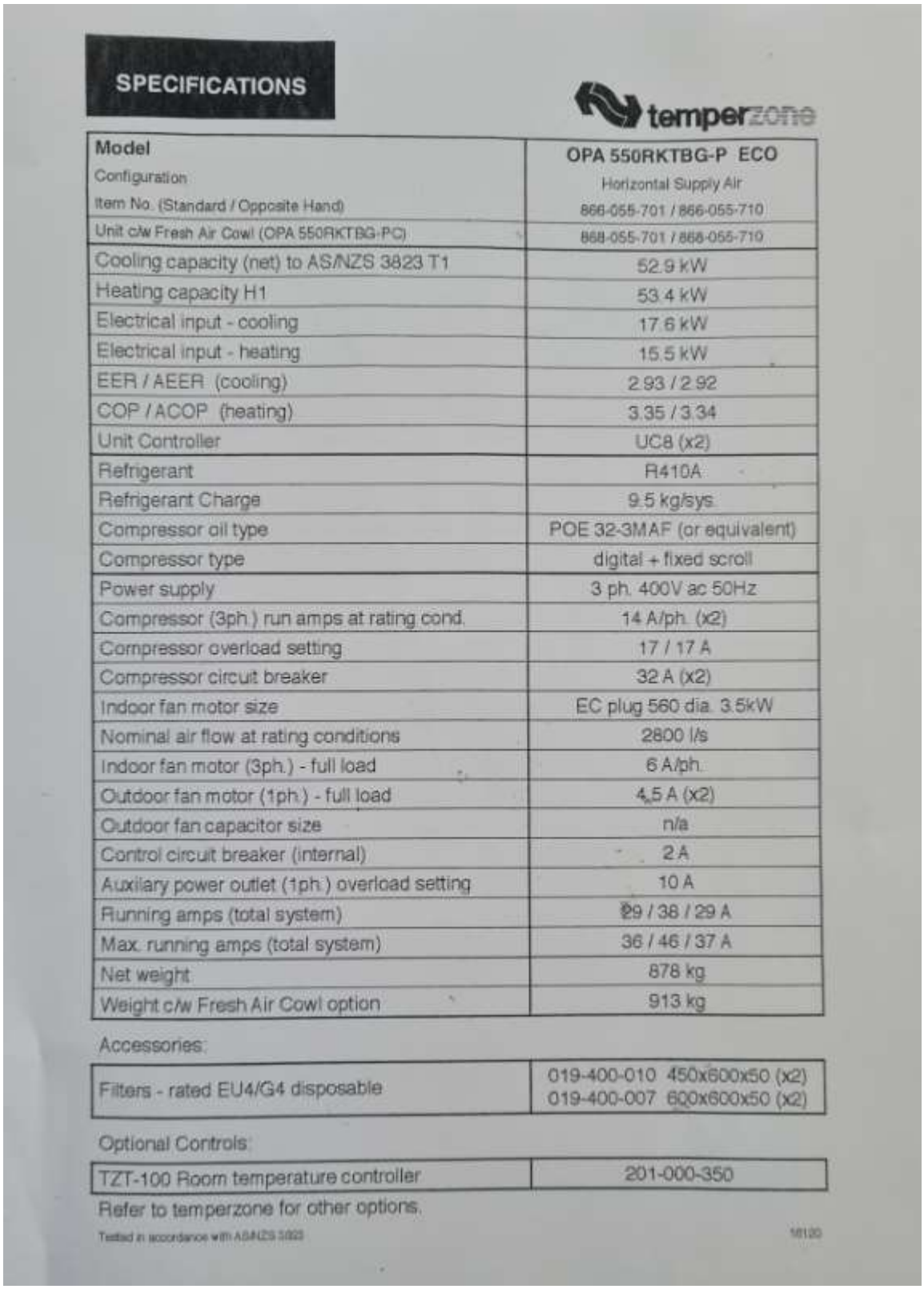
8 Report Format

A separate M&V report is to be developed outlining the data analysis performed and the results obtained

9 Quality Assurance

As this report is being generated after the fact. No QA can be performed

Appendix A – Temperzone OPA 550RKTBG-P ECO Technical Specifications



SPECIFICATIONS

temperzone

Model	OPA 550RKTBG-P ECO
Configuration	Horizontal Supply Air
Item No. (Standard / Opposite Hand)	866-055-701 / 866-055-710
Unit c/w Fresh Air Cowl (OPA 550RKTBG-PC)	868-055-701 / 868-055-710
Cooling capacity (net) to AS/NZS 3823 T1	52.9 kW
Heating capacity H1	53.4 kW
Electrical input - cooling	17.6 kW
Electrical input - heating	15.5 kW
EER / AEER (cooling)	2.93 / 2.92
COP / ACOP (heating)	3.35 / 3.34
Unit Controller	UC8 (x2)
Refrigerant	R410A
Refrigerant Charge	9.5 kg/sys
Compressor oil type	POE 32-3MAF (or equivalent)
Compressor type	digital + fixed scroll
Power supply	3 ph. 400V ac 50Hz
Compressor (3ph.) run amps at rating cond.	14 A/ph. (x2)
Compressor overload setting	17 / 17 A
Compressor circuit breaker	32 A (x2)
Indoor fan motor size	EC plug 560 dia. 3.5kW
Nominal air flow at rating conditions	2800 l/s
Indoor fan motor (3ph.) - full load	6 A/ph.
Outdoor fan motor (1ph.) - full load	4.5 A (x2)
Outdoor fan capacitor size	n/a
Control circuit breaker (internal)	2 A
Auxiliary power outlet (1ph.) overload setting	10 A
Running amps (total system)	29 / 38 / 29 A
Max. running amps (total system)	36 / 46 / 37 A
Net weight	878 kg
Weight c/w Fresh Air Cowl option	913 kg

Accessories:

Filters - rated EU4/G4 disposable	019-400-010 450x600x50 (x2) 019-400-007 600x600x50 (x2)

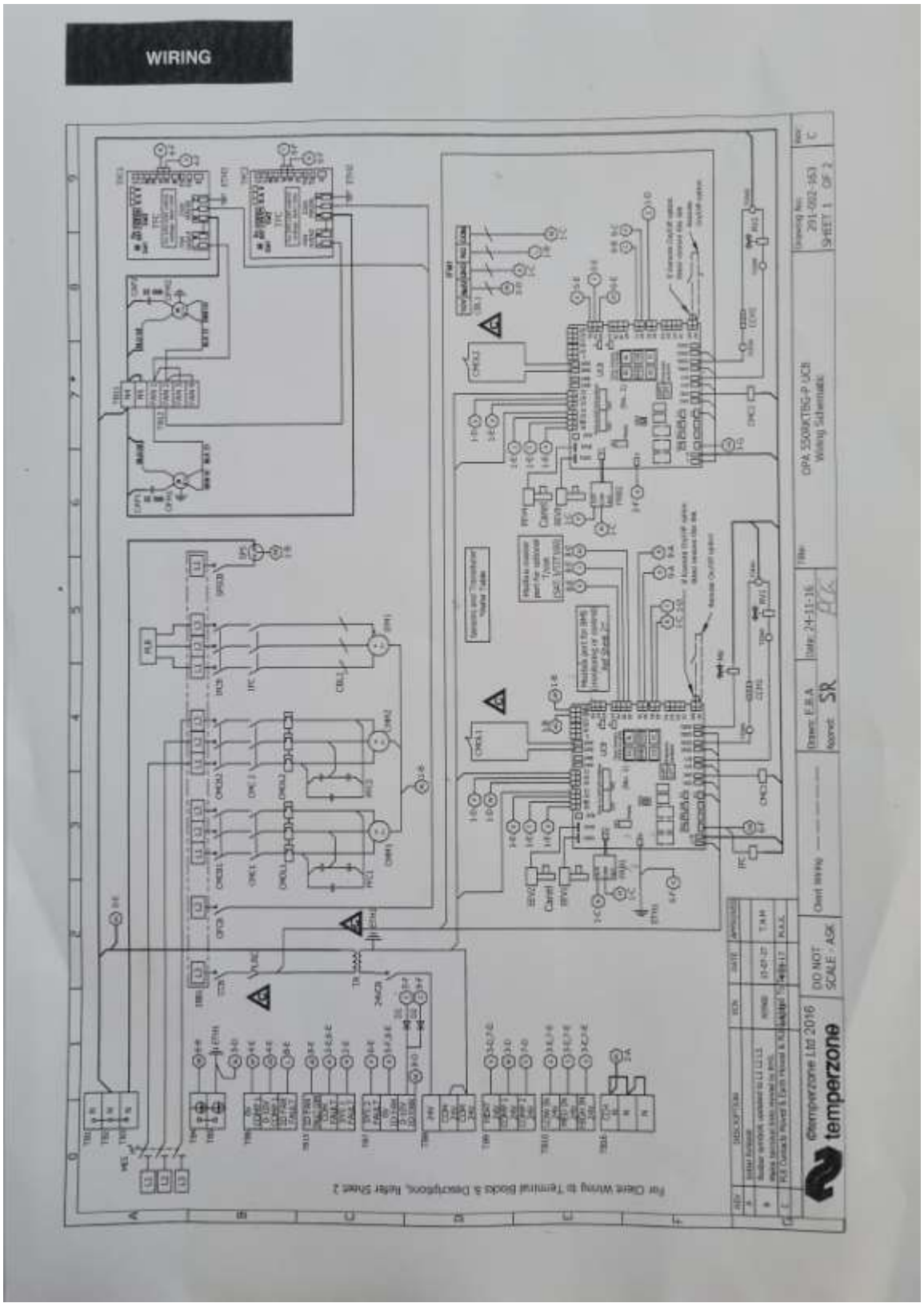
Optional Controls:

TZT-100 Room temperature controller	201-000-350

Refer to temperzone for other options.

Tested in accordance with AS/NZS 3823

Appendix B – Temperzone Drawing 291-002-163 sheet 1 of 2



seam

SOLAR ENERGY ANALYTICS MANAGEMENT

General Specification

STANDARD PACKAGE

1. Wi-Fi Energy Meter (WEM 3080T) x 1
2. Split-Core Current Transformer (150A and 250A optional) x 3
3. 2.4G Wi-Fi Antenna x 1

PHASE

Three Phase.

POWER SUPPLY

Built-in universal power supply.

ANTENNA

External 2.4G antenna with SMA male.

COMMUNICATION

Built-in Wi-Fi.

REPORT INTERVAL & CONTENTS

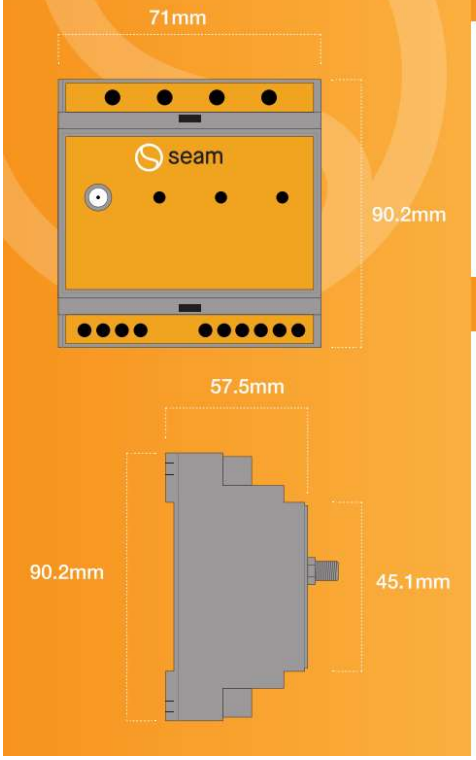
1. Interval: 1-5 minutes interval, typically 1 minute.
2. Contents: Active Energy Forward and Reverse), Active Power, Voltage, Current, Frequency.

CONFIGURATION

1. Wi-Fi access point and webpage for setting SSID and password.
2. Mobile App for setting SSID and password.

MONITORING SCENARIOS

1. Monitor on the cloud.
2. Monitor locally on your PC via WLAN (Http get interface).
3. Integrate with third-party servers, such as your own server, PV output and HomeAssistant (TCP/SSL interface).



Electrical Characteristics

INPUT VOLTAGE

80V ~ 277VAC (Phase Voltage)
140V ~ 480 VAC (Line Voltage)

CT RATING

150A , 250A or 500A optional.

CT DIAMETER

150A: 16mm | 250A: 24.5mm | 500A: 35mm

MEASUREMENT ACCURACY

1. Voltage: ±1.0%
2. Current: ±1.0%
3. Active Power: ±1.0%
4. Active Energy: Class 1 as defined by IEC62053-21

TYPICAL POWER CONSUMPTION

≤2W (220VAC input)

Mechanical Characteristics

WEIGHT

150A Model: 0.62 kg.
250A Model: 1.02kg.

DIMENSION

90.2mm x 71.0mm x 57.5mm (2 DIN pole).

PROTECTION

IP51

AC INPUT

UA-Live wire Phase A,
UB-Live wire Phase B
UC-Live wire Phase C,
UN-Neutral wire.

RS485 INTERFACE

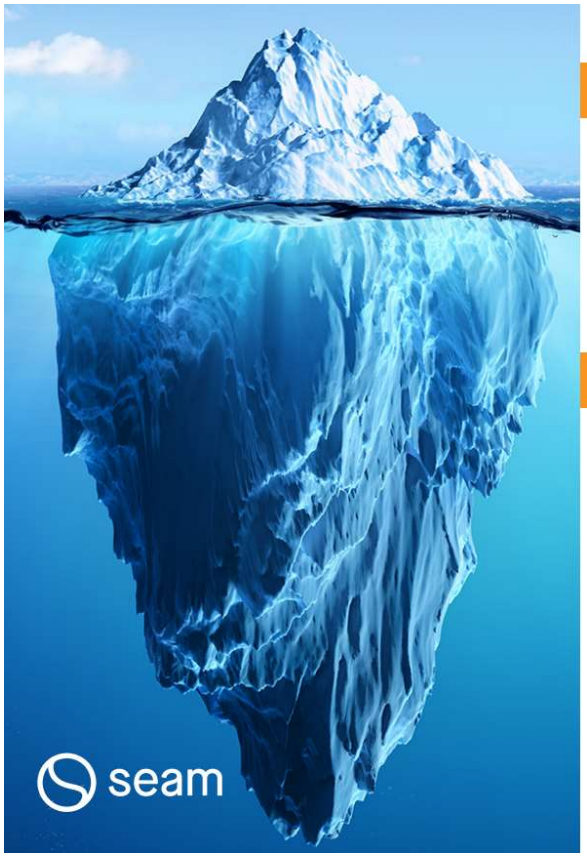
A Positive,
B Negative.

CT

IA+ is Positive Phase A ,
IA- is Negative Phase A;
IB+ is Positive Phase B,
IB- is Negative Phase B;
IC+ is Positive Phase A ,
IC- is Negative Phase C.

SMA PORT

External Antenna Port.



Environmental Conditions

OPERATING TEMPERATURE
-20 ~ +60℃

OPERATING HUMIDITY
5 ~ 95%

ALTITUDE
0 ~ 3000m

Wi-Fi Network & Parameters

WLAN
Channel: Auto
Security: WPA2-PSK

TRANSMIT SPEED
72.2Mbps@20M Bandwidth
150Mbps@40M Bandwidth

WI-FI MODE
IEEE802.11b/g/n, Wi-Fi Channel 1-13

MAXIMUM CONNECTIONS
8

TRANSMIT POWER
18.5dBm@11b
16.5dBm@11g
15.5dBm@11n

WI-FI ANTENNA
External, 5 dBi gain

WI-FI FREQUENCY
2.412 ~ 2.484GHZ

seam

RS485 Interface

PROTOCOL
Modbus-RTU

BAUD RATE(BPS)
1200 | 2400 | 4800 | 9600
9600Bps by default.

DATA FORMAT
"n,8,1"

Cloud Interface

PROTOCOL
Web-based monitoring via Seam.Solar.

DATA INTERVALS
Real time 5 minute aggregated.

Compliance Certificates

CERTIFICATION
RoHS, CE, RCM

RCM

EQUIPMENT
Level 1 Equipment

Tested to CE & IEC Standards

HEALTH AND SAFETY
EN60950-1: 2006+A11;
2009+A1;2010+A12;
2011+A2;2013
AS/NZS 61010-1:2010

EFFECTIVE USE OF THE RADIO SPECTRUM
1. ETSI EN 301 489-1 V2.1.1 (2017-02)
2. ETSI EN 301 489-1 V3.1.1 (2017-02)
3. ETSI EN 300 328 V2.1.1 (2016-11)
4. AS/NZS 4268: 2017
5. AS/NZS CISPR 32:2015

GENERAL REQUIREMENT
Applied Standard: IEC62052-11
Meters of Class: Protective class, Indoor

ACCURACY REQUIREMENT
Applied Standard: IEC62053-21
Meters of Class: Accuracy index class 1

ELECTROMAGNETIC COMPATIBILITY
EN62311:2008

MECHANICAL REQUIREMENT
Applied Standard: IEC62053-21
Meters of Class: Protective class, Indoor

Measurement & Verification Report

Customer: *GMG*

Site: *Carina Library*

Date: 16th *August, 2021*

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1 Executive Summary

A multivariable linear regression model was developed to determine if applying Thermal XR treatment (TXR) to the HVAC system at Carina library would provide energy savings.

It confirmed that the Thermal XR treatment yielded an estimated savings of 52%, or 348 kWh ± 91kWH with a relative uncertainty of 26% at a confidence level of 90%.

Over the testing period where average daily temperature ranged between 21.7 and 27.3 deg Celsius.

Savings outside of the temperature range above cannot be estimated, and annual savings cannot be determined. To ascertain annual savings, a longer baseline period representing a wider temperature range is required.

2 Project Overview

The Energy Conservation Measure being trialled was the application of TXR on the HVAC system at Carina Library. The hypothesis being tested was that the TXR application would yield appreciable energy savings on the HVAC system by improving thermal conductivity of the heat exchanger of the unit.

The M&V option that was selected for this project was Option B; modelling a multi-variable linear regression model.

3 Data collection

Two main sources of data were used; actual energy usage of the HVAC system, and local weather data.

Type	Source
Electrical Energy Used	Retrofit wireless energy meter installed on power supply to HVAC unit
Weather	Wunderground data; https://www.wunderground.com/dashboard/pws/IBRISB1111/table/2021-01-21/2021-01-21/monthly

TABLE 1: DATA SOURCES

4 Baseline Period

Data for the baseline period is 53 days and was collected from 22.01.2021 through to when the TXR service was completed on 15.03.2021. The baseline period energy used without adjustments can be seen below.

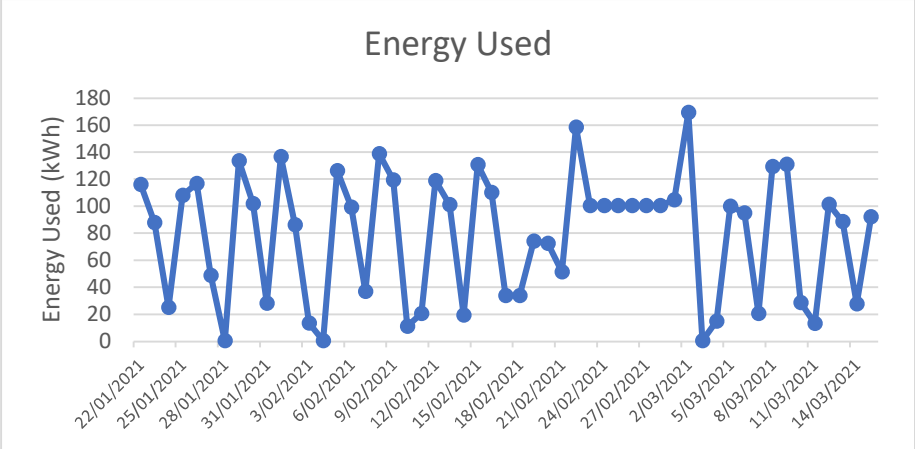

FIGURE 1: BASELINE ENERGY USED

During analysis of the base line data it was identified that on several days the total energy used results were inconsistent with the reported HVAC run time. These days were 17th, 18th, 20th, 21st and 23 - 28th February. It was identified that this was due to a loss of meter communication, as such it was shown to be corrupt. These days were removed from the base line data.

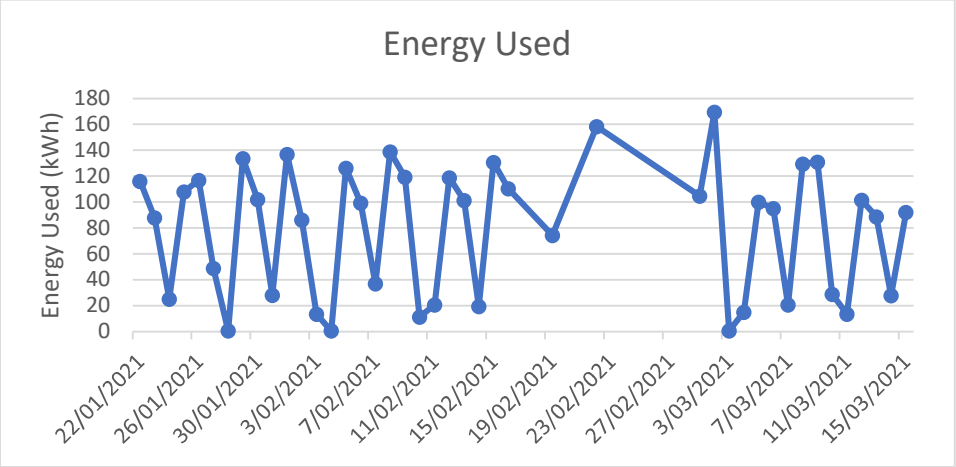

FIGURE 2: BASELINE ENERGY USED, WITH ERRONEOUS DATA REMOVED

5 Reporting Period

Data for the baseline period was collected from 16.03.2021 when the TXR service was completed through to 20.04.2021, representing a period of 77 days.

The reporting period sampling was filtered to suit the temperature range used within the baseline. A reporting temperature range that was equal to the baseline temperature was used. This resulted in an average temperature range of 21.7 and 27.3 deg Celsius. The 25th and 27th of July, as well as the 10th to 16th of April was removed from the dataset for consistency due to data integrity issues, where there was a loss of communication noted.

This reporting period with erroneous data removed can be seen below in Figure 3.

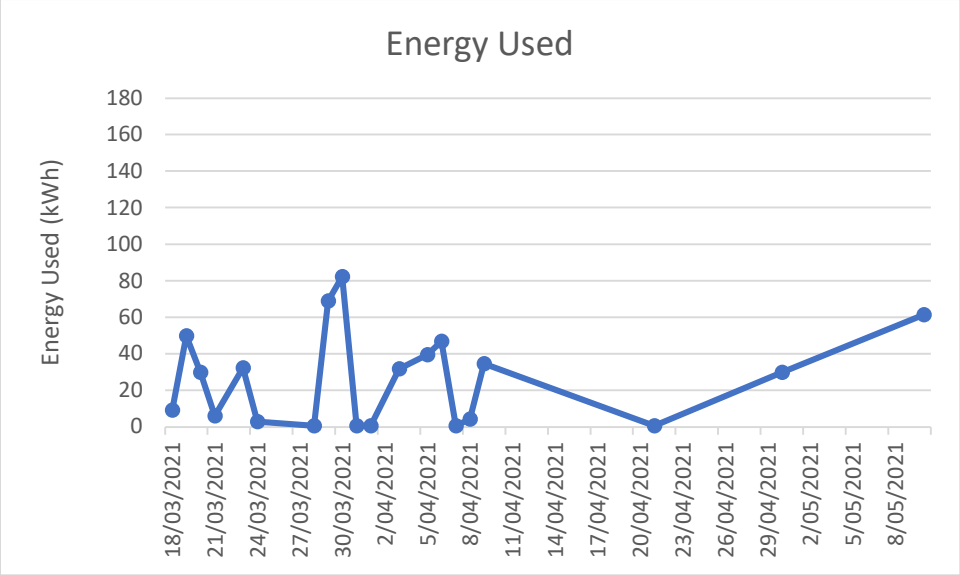

FIGURE 3: REPORTING PERIOD ENERGY USED, WITH ERRONEOUS DATA REMOVED

6 Analysis

A multivariable linear regression model was developed from the base line data. Actual energy used, as reported by the installed energy meter, was taken from the reporting period and was compared against predicted energy usage from the model.

6.1 Variables Modelled

In addition to energy used, the duration the unit was on for, weekday, max temperature, average humidity, average wind speed, rain fall, and dew point were collected for the period.

From this, cooling degree days (CDD), heating degree days (HDD), opening hours rain fall, and opening hours average wind speed, and operating day were calculated.

6.2 Variables Omitted

The hours of occupancy of the building, or any data regarding occupancy were not initially available to model and has been omitted.

The thermal mass of the building is also unknown, and so this cannot be factored into the model.

Ideally, HDD would also be included in the model. However, for the baseline and reporting period, HDD had no impact given the temperature conditions, and so was omitted.

6.3 Selected Model

Several regression models were trialled, to ascertain which variables had a high degree of correlation with the energy used.

From this, it was found that most weather variables were not statistically significant in their relation to energy usage.

The model that had that had the best fit was using average temperature, and a binary variable for whether it was an operating day (Monday, Tuesday, Friday or Saturday).

6.4 Measurement Boundary

Given that the baseline reporting period was limited to 53 days, this model cannot be used as a year-round model for prediction. The boundary in which this model is usable within an average daily temperature of 21.7 and 27.3 deg Celsius.

6.5 Sensitivities

Plotting the residuals against the modelled variables does not appear to demonstrate error sensitivity to any particular range of the variables measured.

6.6 Regression formula

Energy Used = -211.73 + 9.46 x Average Temperature + 101.47 x Monday + 103.04 x Tuesday + 93.15 x Friday + 67.66 x Saturday

A linear form was used, as polynomial or other forms were not deemed appropriate for the variable relationship being modelled.

No intervariable dependency was found when plotting the variables against each other.

Autocorrelation was also not observed.

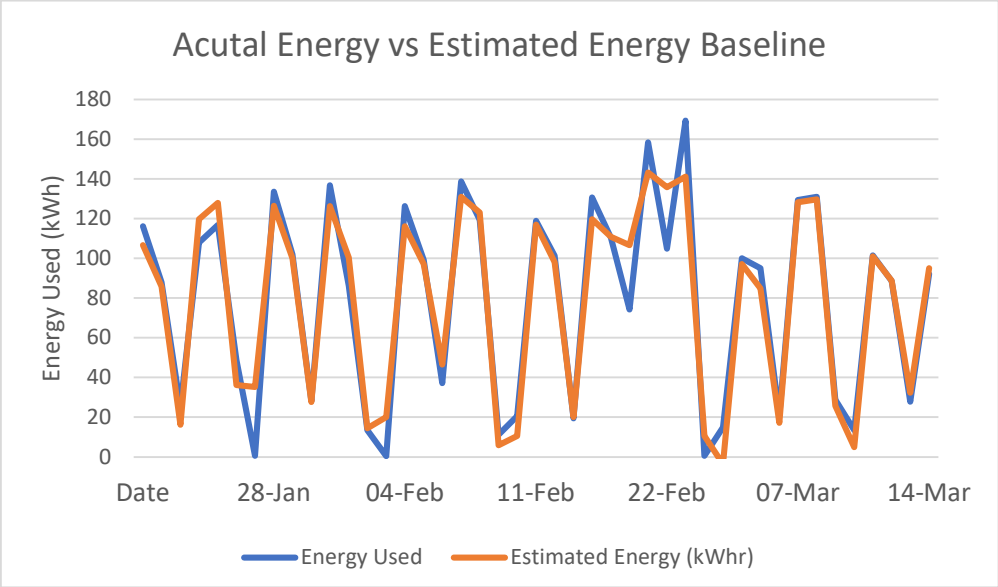

FIGURE 4: ACTUAL VS ESTIMATED ENERGY USED - BASELINE

6.7 Regression Results

The results of the regression can be seen below in Table 2.

Regression Statistics	
Multiple R	0.96767
R Square	0.936386
Adjusted R Square	0.92779
Standard Error	13.46365
Observations	47

TABLE 2: REGRESSION RESULTS

94% of the variation can be explained by the regression; one of several indicators that the model is an appropriate fit. The adjusted R^2 value is also similar to the R^2 value, which is as expected given that only a few independent variables were modelled to reduce the likelihood of interdependencies between them.

A standard error of 13 kWh is indicative of a model with good fit.

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-203.947	40.37987821	-5.050701021	1.20592E-05
Average Temperature	9.12038	1.642841494	5.551588768	2.54245E-06
Monday	102.1352	5.859235231	17.43149668	1.98452E-19
Tuesday	103.5511	6.447072122	16.06172156	2.90419E-18
Friday	93.58693	6.124170361	15.28156806	1.4486E-17
Saturday	71.55052	6.498670916	11.01002292	3.12447E-13

TABLE 3: VARIABLE T STAT AND P VALUES

High t Stats and low P-values for both independent variables of less than 0.02 indicate that there is strong evidence that they have a significant impact on energy used.

7 Results

The estimated results compared to the actual energy used in the reporting period can be seen below in Figure 5.

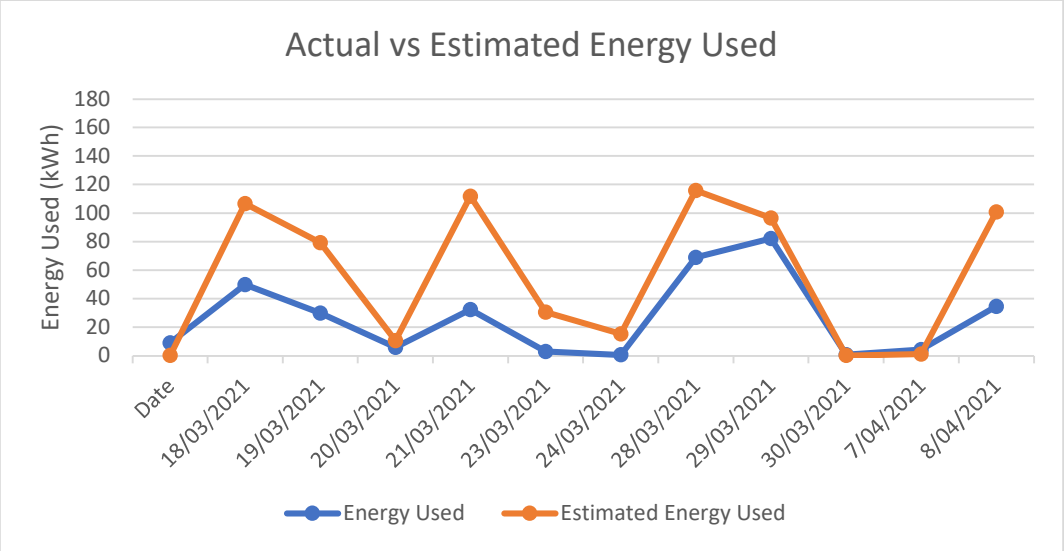

FIGURE 5: ACTUAL VS ESTIMATED ENERGY USED - REPORTING

7.1 Savings

The baseline (adjusted to the conditions of the reporting period) less the actual energy used, yielded an estimated savings of 348 kWh ± 91 kWh with a relative uncertainty of 26% at a confidence level of 90%.

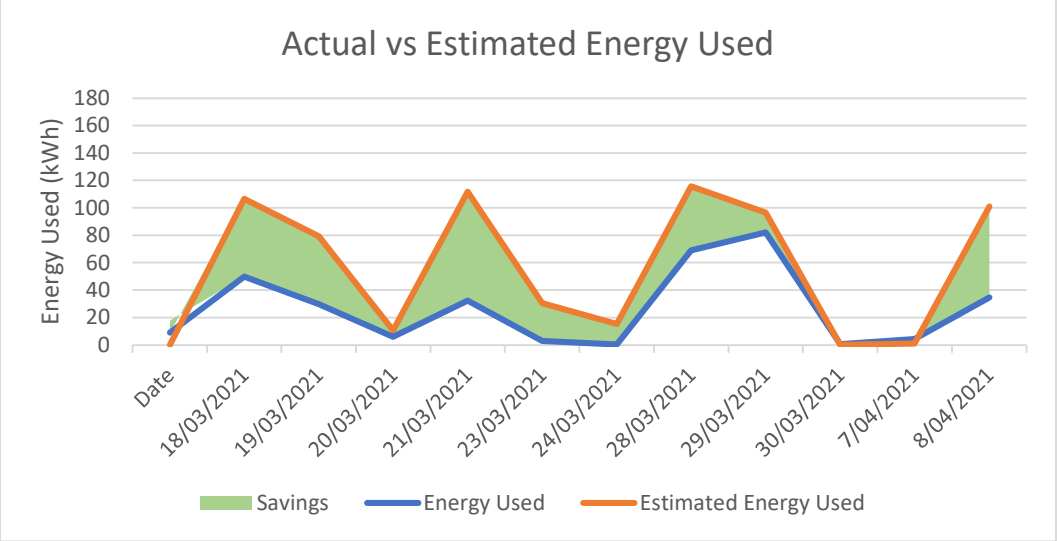

FIGURE 6: ESTIMATED SAVINGS

8 Appendix 1: Regression Results

8.1.1 Base line

Date	Energy Used	Average Temperature	Monday	Tuesday	Friday	Saturday	Estimated Energy (kWhr)
22/01/2021	116.1	23.8	0	0	1	0	106.579
23/01/2021	87.87	24.3	0	0	0	1	85.81147
24/01/2021	25.13	24.1	0	0	0	0	16.26416
25/01/2021	107.94	24.3	1	0	0	0	119.6268
26/01/2021	116.74	25	0	1	0	0	127.8179
27/01/2021	48.78	26.2	0	0	0	0	36.13092
28/01/2021	0.58	26.1	0	0	0	0	35.18489
29/01/2021	133.53	25.9	0	0	1	0	126.4458
30/01/2021	101.89	25.8	0	0	0	1	100.002
31/01/2021	28.13	25.3	0	0	0	0	27.61659
1/02/2021	136.78	25	1	0	0	0	126.2491
2/02/2021	86.22	22.1	0	1	0	0	100.3828
3/02/2021	13.55	23.9	0	0	0	0	14.37209
4/02/2021	0.56	24.5	0	0	0	0	20.0483
5/02/2021	126.3	24.8	0	0	1	0	116.0394
6/02/2021	99.17	25.5	0	0	0	1	97.1639
7/02/2021	37.11	27.3	0	0	0	0	46.53732
8/02/2021	138.7	25.5	1	0	0	0	130.9792
9/02/2021	119.38	24.5	0	1	0	0	123.0877
10/02/2021	11.24	23	0	0	0	0	5.857759
11/02/2021	20.6	23.5	0	0	0	0	10.58794
12/02/2021	118.9	24.9	0	0	1	0	116.9854

13/02/2021	101.23	25.6	0	0	0	1	98.10994
14/02/2021	19.37	24.5	0	0	0	0	20.0483
15/02/2021	130.65	24.3	1	0	0	0	119.6268
16/02/2021	110.28	23.2	0	1	0	0	110.7892
19/02/2021	74.25	23.8	0	0	1	0	106.579
22/02/2021	158.41	26.8	1	0	0	0	143.2777
1/03/2021	104.81	26	1	0	0	0	135.7094
2/03/2021	169.34	26.4	0	1	0	0	141.0624
3/03/2021	0.57	23.5	0	0	0	0	10.58794
4/03/2021	14.89	22	0	0	0	0	-3.6026
5/03/2021	100.08	22.8	0	0	1	0	97.11864
6/03/2021	94.94	24.2	0	0	0	1	84.86543
7/03/2021	20.65	24.2	0	0	0	0	17.21019
8/03/2021	129.28	25.2	1	0	0	0	128.1411
9/03/2021	130.89	25.2	0	1	0	0	129.71
10/03/2021	28.8	25.1	0	0	0	0	25.72452
11/03/2021	13.41	22.9	0	0	0	0	4.911722
12/03/2021	101.49	23.2	0	0	1	0	100.9028
13/03/2021	88.58	24.6	0	0	0	1	88.64957
14/03/2021	27.76	25.8	0	0	0	0	32.34678
15/03/2021	92.07	21.7	1	0	0	0	95.02986

8.1.2 Reporting Period

Date	Energy Used	Average Temperature	Monday	Tuesday	Friday	Saturday	Estimated Energy Used
18/03/2021	9.09	22.4	0	0	0	0	0.181541
19/03/2021	49.85	23.8	0	0	1	0	106.579
20/03/2021	29.77	23.6	0	0	0	1	79.18921

21/03/2021	5.96	23.5	0	0	0	0	10.58794
23/03/2021	32.28	23.3	0	1	0	0	111.7353
24/03/2021	2.86	25.6	0	0	0	0	30.4547
28/03/2021	0.6	24	0	0	0	0	15.31812
29/03/2021	68.9	23.9	1	0	0	0	115.8427
30/03/2021	82.24	21.7	0	1	0	0	96.59869
31/03/2021	0.63	21.2	0	0	0	0	-11.1709
1/04/2021	0.64	20.6	0	0	0	0	-16.8471
3/04/2021	31.79	21.5	0	0	0	1	59.32245
5/04/2021	39.48	21.3	1	0	0	0	91.24571
6/04/2021	46.9	21.3	0	1	0	0	92.81454
7/04/2021	0.64	22.4	0	0	0	0	0.181541
8/04/2021	4.27	22.5	0	0	0	0	1.127577
9/04/2021	34.58	23.2	0	0	1	0	100.9028
21/04/2021	0.63	21.6	0	0	0	0	-7.38675
30/04/2021	29.92	21.2	0	0	1	0	81.98206
10/05/2021	61.44	20.6	1	0	0	0	84.62346