Measurement & Verification Report

Air Conditioning Replacements

Project Summary

In the Summer of 2021, 12 aging and inefficient air conditioning units were replaced with 10 new, high efficiency units, funded by the Salix Public Sector Decarbonisation Scheme (PSDS). This project was expected to have a significant impact on the energy consumption of the cooling requirement within each room. There were no planned changes to the baseline in terms of occupancy or temperature settings (compared to a pre-covid baseline).

This M&V Report is based on the principals of measurement and verification outlined in the International Performance Measurement and Verification Protocol (IMPVP) Volume 1, EVO 10000 –1:2012 as detailed in Table 1 below.

The replacement of these air conditioning units has resulted in energy savings of 41,537.89 kWh per year with an annual cost saving of £6,314 (2021 pricing) and £10,509 (2022+ pricing). 9.68 tCO_2e per year savings have also been calculated. In comparison with the estimations outlined in our original Salix application, the pre-project kWh usage was found to be reduced by 34% from an estimated 69,669 kWh to a measured 45,576.02 kWh. This has resulted in a slightly smaller saving (reduced by 11%) in terms of annual costs. A correspondingly longer payback period of 9.37 years was calculated using the 2021 pricing, however when calculated using 2022 prices, the payback period is greatly reduced to 5.63 years (compared with 8.31 years expected). However, as the retrofit consumption is also much smaller than expected (4,038 kWh compared with 22,847 kWh), greater % savings in terms of kWh (91% compared with 67% predicted) and increased annual tCO_2e savings have been observed (9.68 tCO_2e per year).

Table 1: M&V Summary

Framework	
M&V plan	Project UoR152 Air Conditioning Replacements M&V Plan (dated January 2021)
IPMVP Option	Option A (Retrofit Isolation)

Measurement	
Measurement Method	Sinergy e-tracker energy monitor fitted at the supply within the distribution board
Measurement Boundary	Air conditioning units subject to the retrofit project
Monitoring Period	1 week for both baseline and verification activities
Analysis	
Savings Determination	Avoided demand
Basis of Routine Adjustments	A mathematical model was constructed according to relevant independent variables (CDD weather data), the results of which indicated removing weather data from the model.
Target Uncertainty	Total quantifiable accuracy of the savings +/- 7.21%
Reporting	
Reporting Schedule	Year 0 Report – Immediately following ECM completion Repeat measurements could be taken in subsequent years, however for a straightforward equipment replacement project, this is felt to be unnecessary, as results are unlikely to change.

1 Facility Consumption Data

The following section presents the summary energy consumption data. Measured data were collected for the baseline/pre-retrofit sample over a period of 1 week between 23rd June 2021, and ends on 29th June 2021, which represents a full operational cycle of the ECM. The reporting period data were gathered, also for one week, between 18th January 2022-24th January 2022. There were no deviations from the M&V plan and no power outages or data gaps.

Table 2 provides an example of the measured data, without any adjustment, from one sample during the baseline and reporting period (1 week). Figure 1 presents example data from the baseline monitoring.

Table 2: Baseline and reporting period example data (Sports Park gymnasium)

Sample location	Baseline energy consumption (kWh)	Reporting period energy consumption (kWh)	Savings (kWh)	Savings (%)
Sports Park gymnasium (unit 1)	5,285.80	1,201.20	4,084.60	77.27

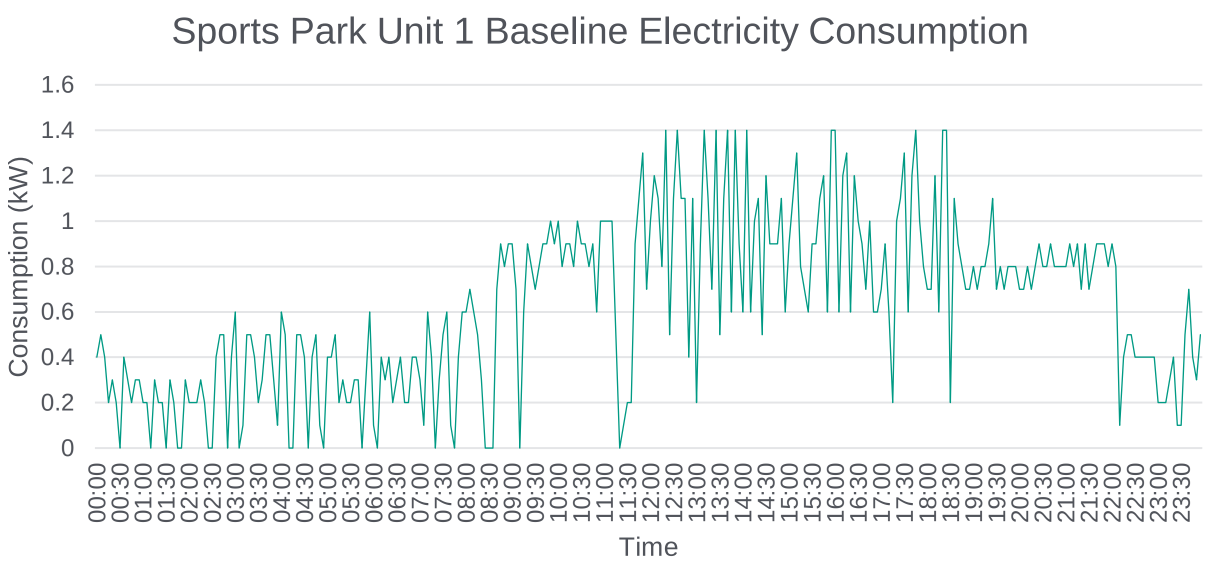


Figure 1: Baseline electricity consumption (23rd June 2021)

Data were gathered for 16.67% of the baseline population and 10% of the post-retrofit population. This data was then subjected to the routine and non-routine adjustments described in Section 2.

2 Baseline period adjustment data

The energy savings were subject to a number of routine and non-routine (independent) baseline adjustments according to the calculations and appendix data provided within the M&V plan. In summary, only local external temperature data were assessed for possible routine adjustment inclusion in the computational models.

Only two spaces were in operation during the baseline and reporting periods due to home working surround the covid-19 pandemic. Therefore, only the Sports Park gymnasium units were able to be monitored as this site remained operational as a public space. These data were then applied to typical pre-post pandemic occupancy patterns for each space (M&V Plan, Appendix 1). Those air conditioning units where consumption was unable to be measured, ratios based on kW rated power were also applied to the empirical data gathered from the Sports park units.

A. Independent Variables/Routine Adjustments

Independent variables (routine adjustments) include factors that can affect the appliances energy consumption or demand and that may be systematically included to determine the periodic adjustment of the baseline during the reporting period by way of mathematical models. For this project, the air conditioning unit electricity consumption was assumed to be affected by external temperature, as per section 3C of the associated M&V plan, and required regression analysis and potentially consequent baseline data adjustment for this ECM.

Meteorological data were downloaded from the weather station located nearest to the project site, the University of Reading atmospheric observatory, Reading, Berkshire (Latitude 51.44136°N, Longitude 0.93807°W, National Grid Reference (41) 739 719). Dry-bulb air temperature and associated cooling degree days were downloaded at 5-minute intervals for the baseline and retrofit/report period dates, using a range of base temperatures (0.5° C increments from 15-20° C). An investigation was made to determine the appropriate base temperature (Appendix 1). Analysis revealed that 15° C was the best fit for base temperature (Figure 2), however the relationship was not significant enough for inclusion into the final model (R^2 0.3571).

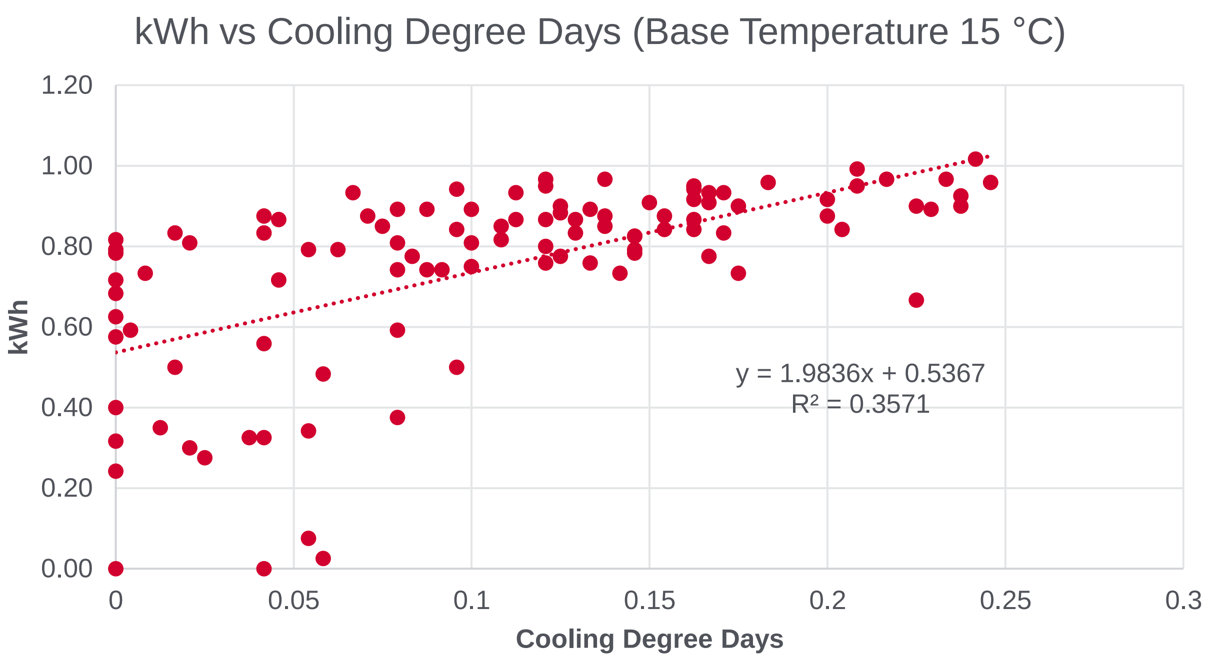


Figure 2: Relationship between electricity consumption and external temperature (CDD with 15℃ base temperature)

Therefore, baseline demand for each location was constructed from the appropriate monitored unit data and applied to occupancy and kW rating for each location and unit.

B. Baseline Static Factors

There were no unforeseen non-routine adjustments (static factors) during the baseline or reporting periods. The operating conditions and personal remained constant throughout the monitoring periods.

However, with respect to the covid-19 lockdown, the baseline and reporting periods are adjusted in order to scale the energy consumption and savings to a more realistic annual figure. The utilisation in terms of hours of occupancy is provided in the associated M&V Plan (Appendix I)

C. Adjustments for Interactive Effects

No adjustment required.

3 Energy Savings Calculations

Table 3 presents the methods for data adjustment according to changes in independent variables and static factors to determine the avoided demand.

Table 3: Method for baseline adjustment

Retained Option	Equation
Avoided demand (kWh)	Avoided Demand = Baseline demand (-) Reporting period energy (±) **Routine** adjustments to period conditions (±) **Non-routine** adjustments to period conditions

Table 4 displays the measured data from the baseline and reporting periods. As per the M&V plan, electricity consumption costs used for savings calculation (baseline or reporting period) are based on rates effective during the reporting period and were established at 0.152 p/kWh including VAT for electric. CO_2 equivalent ($kgCO_2e$) savings were calculated using the UK Government Department for Business, Energy and Industrial Strategy (BEIS) figures for 2020; 0.23314 $kgCO_2e$ per kWh for grid electricity.

Table 4: Weekly energy savings, using pre-covid (February 2020) baseline meals data

Location	Unit	Baseline annual kWh consumption	Reporting annual kWh consumption	Annual savings (kWh)	Annual savings (£)	Annual savings (%)	Annual savings ($kgCO_2e$)
London Road	Rm 120 Unit 1	1,882.58	81.54	1,801.04	273.76	95.67	419.89
London Road	Rm 120 Unit 2	1,882.58	81.54	1,801.04	273.76	95.67	419.89
JJ Thompson	Room 129 No.1	4,303.33	118.00	4,185.33	636.17	97.26	975.77
JJ Thompson	Room 129 No.2	4,303.33	283.20	4,020.13	611.06	93.42	937.25
JJ Thompson	Room 129 No.3	4,303.33	283.20	4,020.13	611.06	93.42	937.25
Typography	Room C2	4,303.33	335.12	3,968.21	603.17	92.21	925.15
Sports Park	Gym Gr No.1	5,285.80	1,201.20	4,084.60	620.86	77.27	952.28

Sports Park	Gym Gr No.2	8,930.13	1,201.20	7,728.93	1,174.80	86.55	1,801.92
Harry Nursten	Room 103	3,012.33	118.00	2,894.33	439.94	96.08	674.78
Meteorology	Room 1L34	3,012.33	335.12	2,677.21	406.94	88.88	624.17
London Road	Rm G11 Unit 2	1,301.55	0.00	1,301.55	197.84	100.00	303.44
JJ Thompson	Room 24	3,055.37	0.00	3,055.37	464.42	100.00	712.33
Totals		45,576.02	4,038.13	41,537.89	6,313.76	91.14	9,684.14

4 Comparison of actual versus predicted savings

A summary of the energy savings predicted compared with the measured data is displayed in Table 5. The predicted pre-project kWh estimates were overstated, however the percentage kWh savings are larger than predicted (91% compared with 67% estimation) due to the improved efficiencies/higher COP of the replacement units, the removal of several units and the resizing and reduction of the kW load of several of the new units. The inclusion of PIR sensors to the replacement units has greatly reduced the consumption as previously several units were left on overnight and when the rooms were unoccupied.

The annual energy consumption post-project is much reduced at only 4,038 kWh consumed per year (compared with 22,847 kWh expected). However, as the baseline consumption of the pre-retrofit units was 34% less than that predicted, this has led to the payback period increasing from 8.31 years to 9.37 years using current costs (comparable with the application estimates), despite achieving the expected project cost. However, due to energy price increases in 2022, when using the new p/kWh rate, the payback period has been calculated at 5.63 years which is very favourable (annual savings have been increased to £10,509 per year, from the predicted £7,117 based on last year's prices). Savings of 9.68 tCO_2e and 41,537.89 kWh (only 11% lower than expected) per year are valuable achievements.

Table 5: Energy conservation measure projected savings

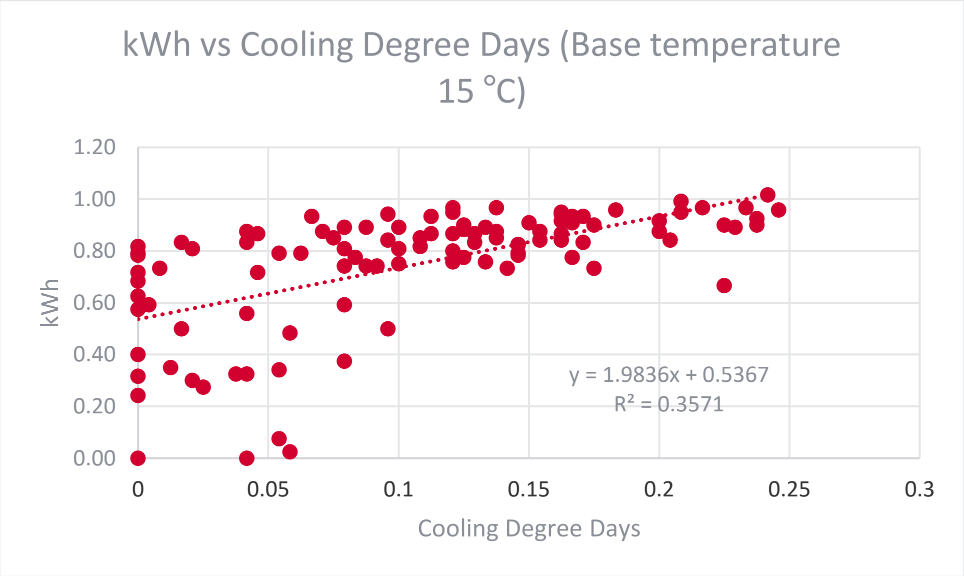
Calculation	Original Salix Application	Actual
Annual kWh Pre-Project	69,669	45,576.02
Annual kWh Post-Project	22,847	4,038.13
Annual Savings (kWh)	46,822	41,537.89
Annual Savings (% kWh)	67.00	91.14
Project Cost	£59,163.78	£59,163.78
Annual Financial Savings (2021-2021)	£7,117	£6,314
Annual Financial Savings (2022+)	-	£10,509

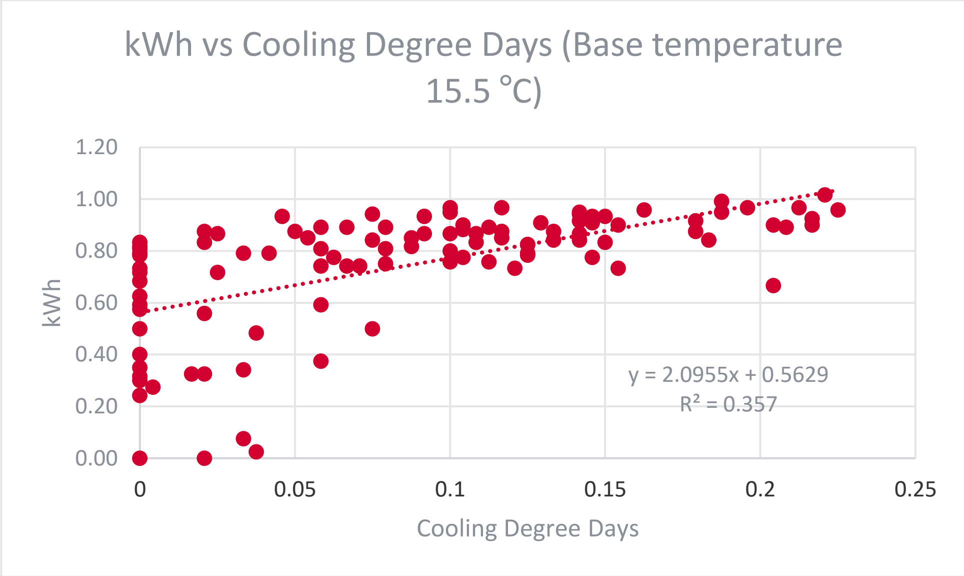
Payback (Years, 2021-2021)	8.31	9.37
Payback (Years, 2022+)	-	5.63
tCO_2e Pa	10.92	9.68

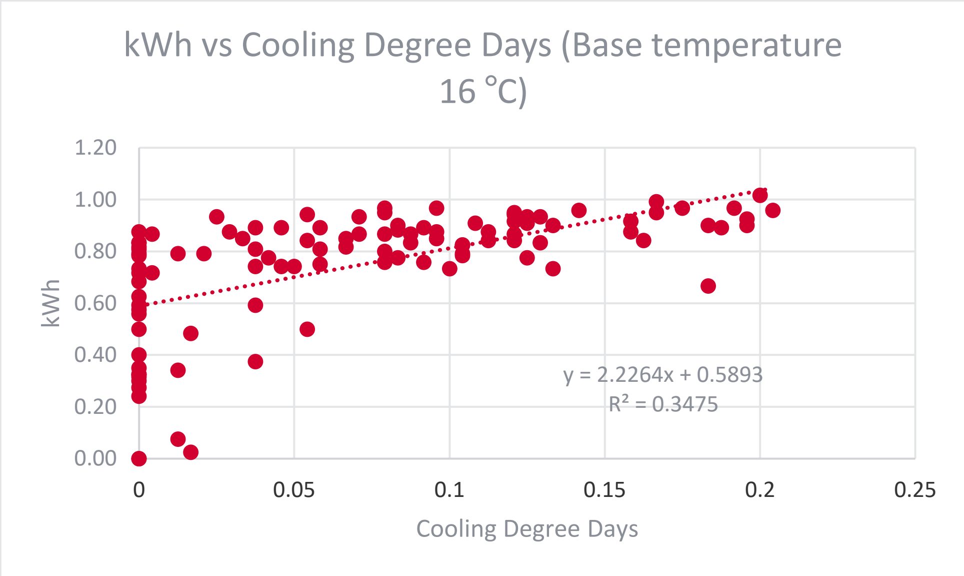
*Converted from the original Salix emission factors to the BEIS emission factors to achieve consistency with other reporting

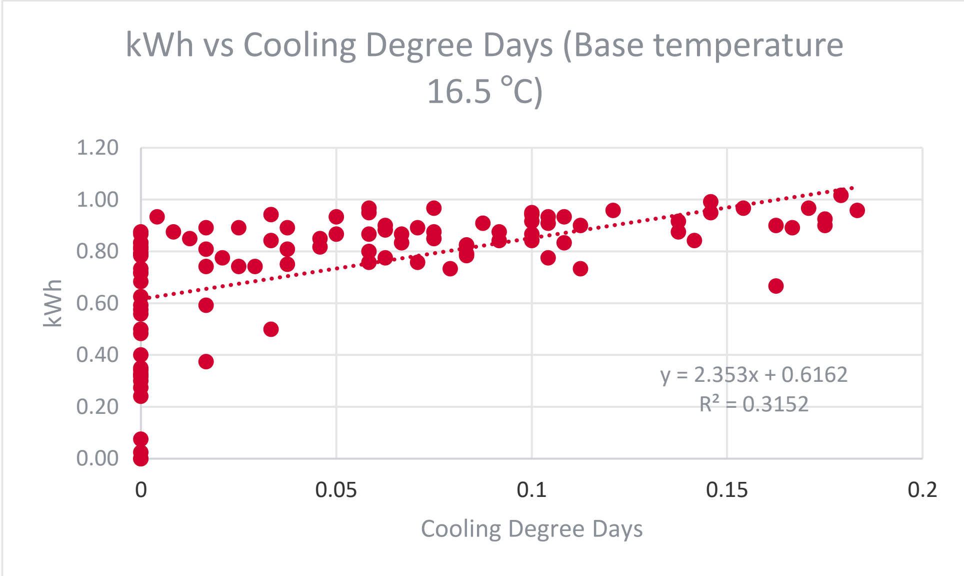
APPENDIX 1 – BASE TEMPERATURE ANALYSIS FOR COOLING DEGREE DAY REGRESSION

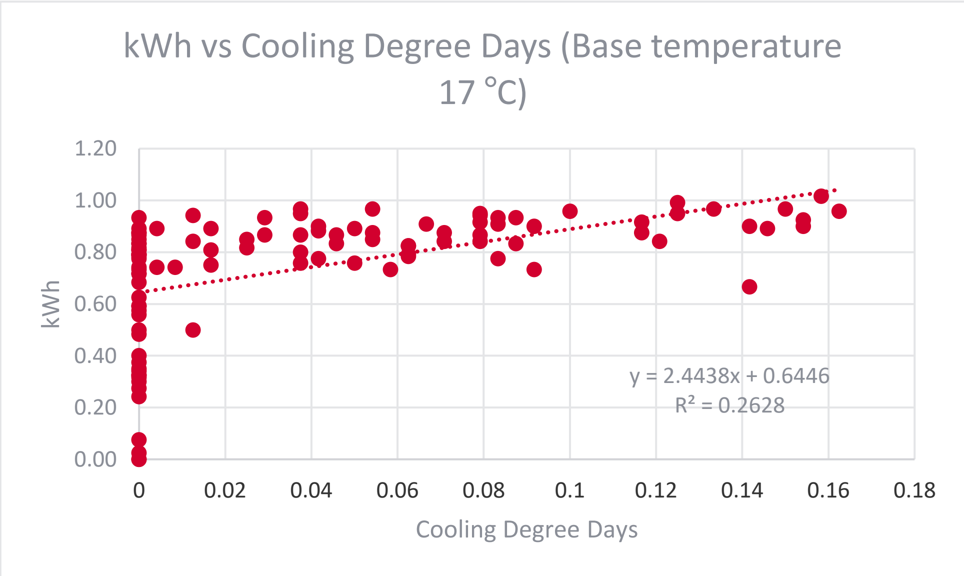
5-minute temperature data were gathered for the week of study for both the baseline and retrofit monitoring periods. Following CIBSE TM41 best practice, cooling degree day data were then extracted for a range of base and plotted against electricity consumption to determine the relationship between energy use and external temperature (below).

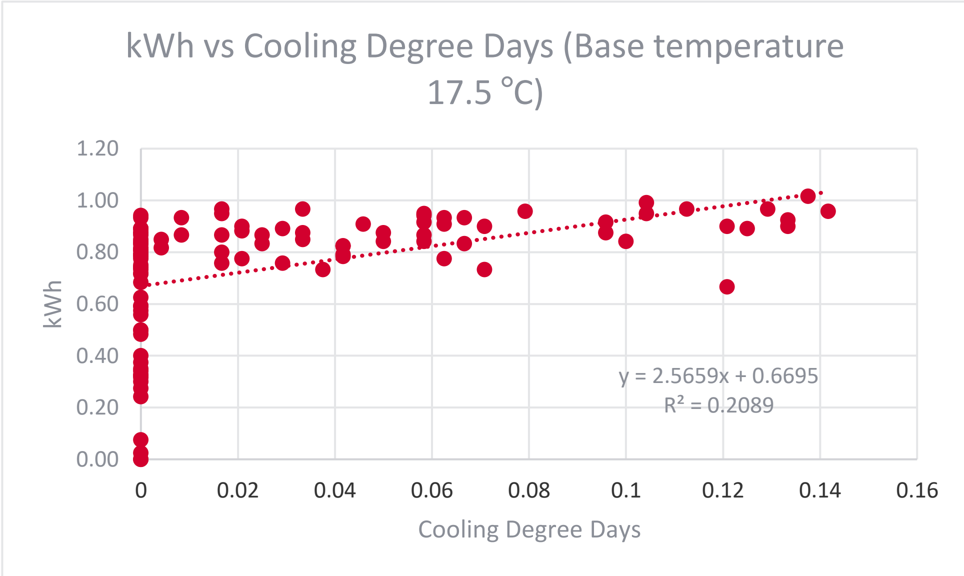


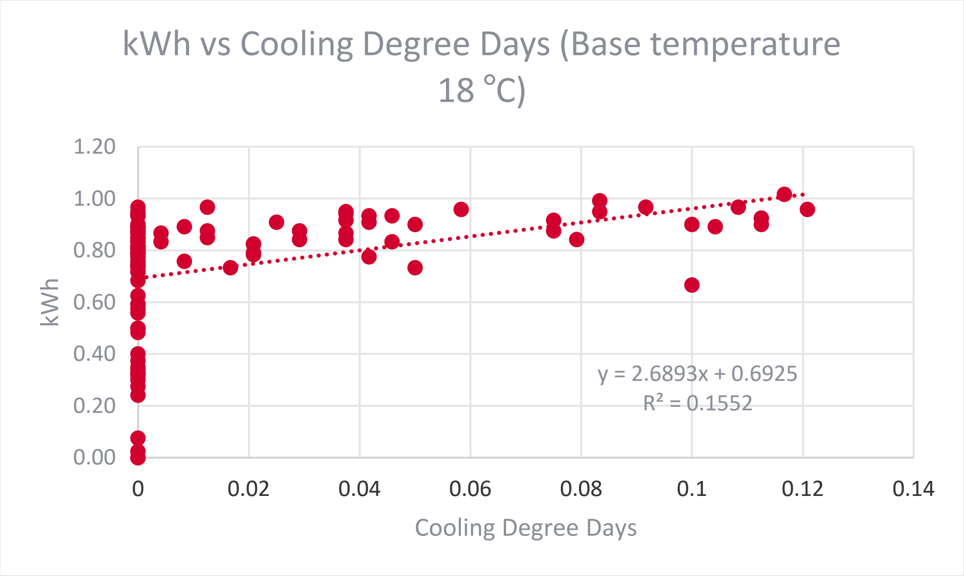


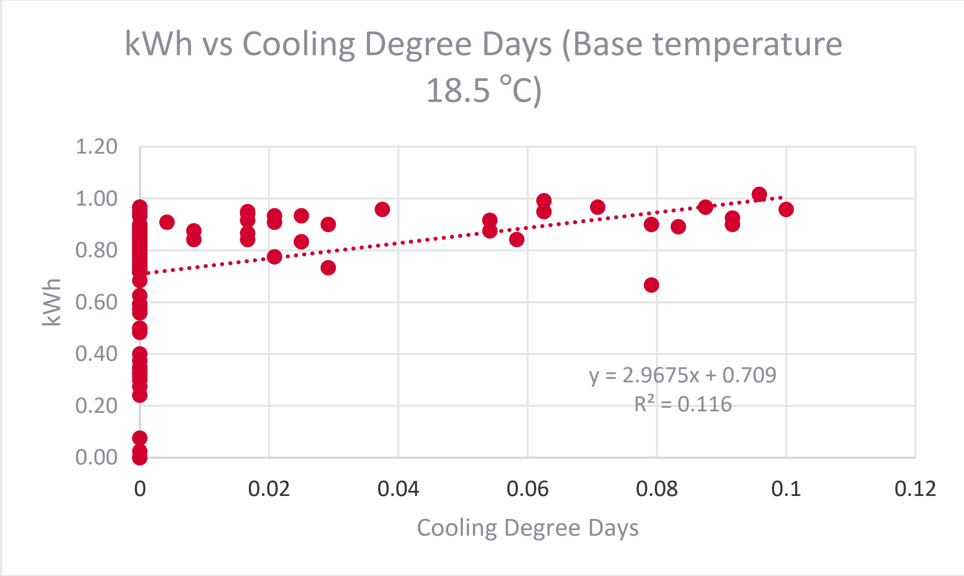

kWh vs Cooling Degree Days (Base temperature 16 °C)
kWh
Cooling Degree Days
y = 2.2264x + 0.5893
R² = 0.3475

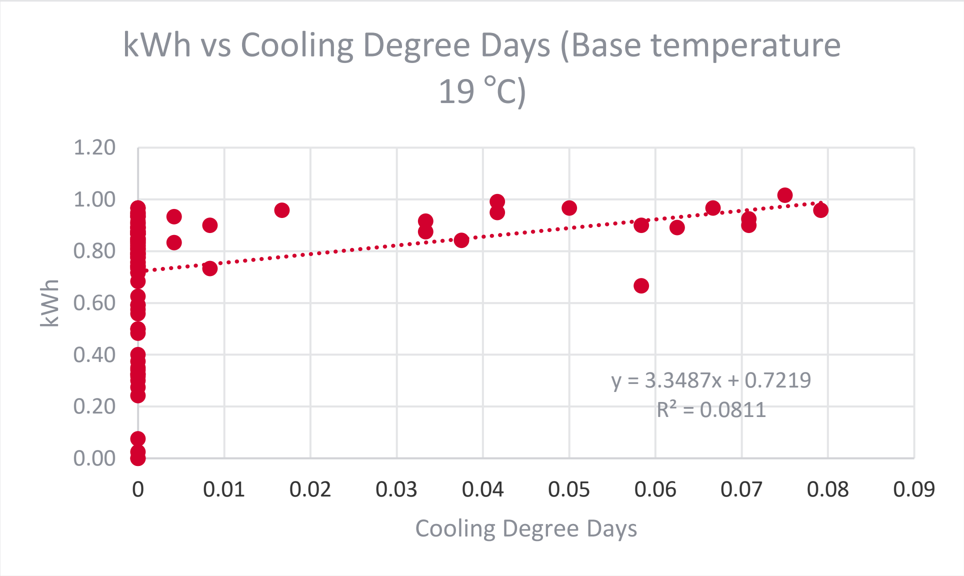

kWh vs Cooling Degree Days (Base temperature 16.5 °C)
kWh
Cooling Degree Days
y = 2.353x + 0.6162
R² = 0.3152

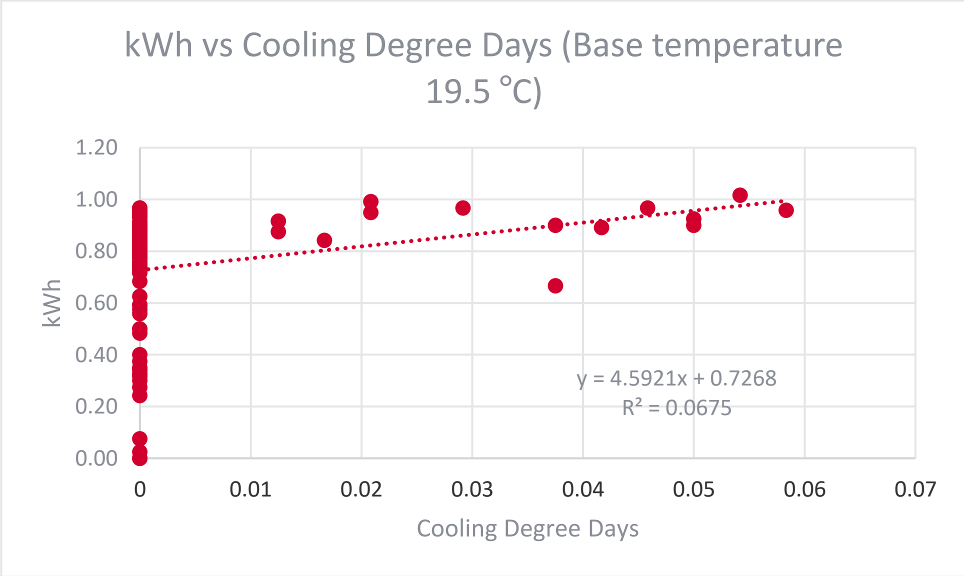

kWh vs Cooling Degree Days (Base temperature 17 °C)
kWh
Cooling Degree Days
y = 2.4438x + 0.6446
R² = 0.2628

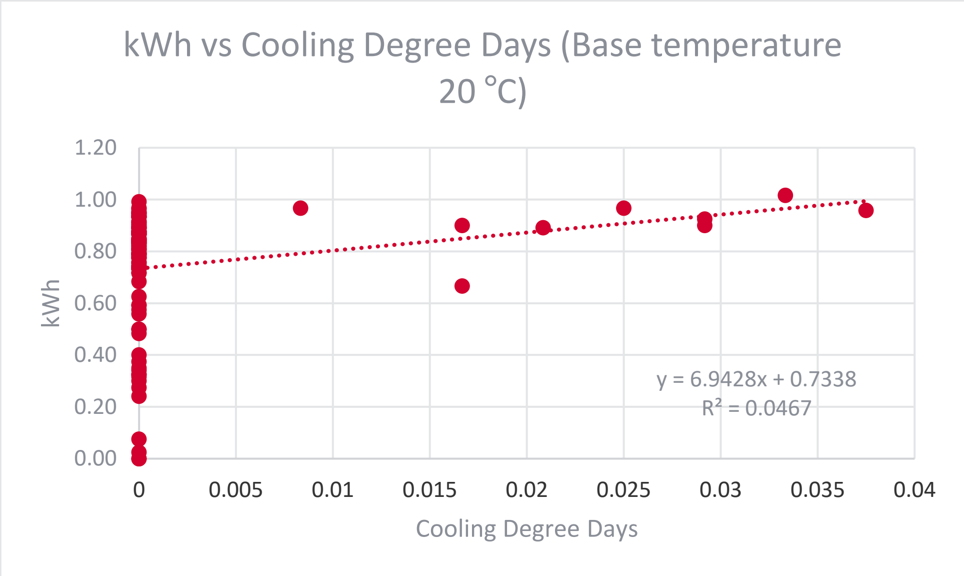

kWh vs Cooling Degree Days (Base temperature 17.5 °C)
kWh
Cooling Degree Days
y = 2.5659x + 0.6695
R² = 0.2089


kWh vs Cooling Degree Days (Base temperature 18 °C)
kWh
Cooling Degree Days
y = 2.6893x + 0.6925
R^2 = 0.1552


kWh vs Cooling Degree Days (Base temperature 18.5 °C)
kWh
Cooling Degree Days
y = 2.9675x + 0.709
R^2 = 0.116


kWh vs Cooling Degree Days (Base temperature 19 °C)
kWh
Cooling Degree Days
y = 3.3487x + 0.7219
R^2 = 0.0811


kWh vs Cooling Degree Days (Base temperature 19.5 °C)
kWh
Cooling Degree Days
y = 4.5921x + 0.7268
R^2 = 0.0675


kWh vs Cooling Degree Days (Base temperature 20 °C)
1.20
1.00
0.80
0.60
0.40
0.20
0.00
kWh
y = 6.9428x + 0.7338
R² = 0.0467
0
0.005
0.01
0.015
0.02
0.025
0.03
0.035
0.04
Cooling Degree Days