The Innovation Hub

for Affordable Heating and Cooling

Report #001

Exergenics Chiller Staging App

Final Project Report

20/05/2022

Exergenics Pty Ltd

About i-Hub

The Innovation Hub for Affordable Heating and Cooling (i-Hub) is an initiative led by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) in conjunction with CSIRO, Queensland University of Technology (QUT), the University of Melbourne and the University of Wollongong and supported by Australian Renewable Energy Agency (ARENA) to facilitate the heating, ventilation, air conditioning and refrigeration (HVAC&R) industry's transition to a low emissions future, stimulate jobs growth, and showcase HVAC&R innovation in buildings.

The objective of i-Hub is to support the broader HVAC&R industry with knowledge dissemination, skills-development and capacity-building. By facilitating a collaborative approach to innovation, i-Hub brings together leading universities, researchers, consultants, building owners and equipment manufacturers to create a connected research and development community in Australia.

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program.
The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

Primary Project Partner

Exergenics

Exergenics Chiller Staging App

This project aims to integrate the Exergenics' novel chilled water plant optimisation solution with i-Hub's Data Clearing House, and use it to demonstrate energy savings and renewable energy demand profile matching, in a CSIRO building.

This will help validate the efficacy of the Data Clearing House as a tool for Exergenics to rapidly onboard buildings. It will also provide a rigorous case-study of Exergenics' software that can be used to develop the market for Exergenics services, and pave the way for future solutions that leverage building data to achieve material outcomes.

Lead organisation

Exergenics

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Contact name

Iain Stewart

Email

iain.stewart@exergenics.com

Project website

exergenics.com

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1. SUMMARY

1.1 Executive summary

The Data Clearing House, developed by CSIRO & i-Hub, is a single location for accessing energy and building data for CSIRO assets, intended for widespread adoption by the industry. Exergenics was engaged in September 2021 to leverage the technology by interfacing to the system and extracting data from the Synergy building at CSIRO's Black Mountain site, in Canberra, for use in their cloud-based chilled water optimisation software.

With every chilled plant being unique, human optimisation is time consuming and there is a serious shortage of engineers skilled to do this work. Optimal setpoints for chilled water plants can deliver significant energy savings without equipment upgrades or new controllers, but these setpoints are challenging to find.

Exergenics' cloud-based AI optimisation addressed that challenge and achieve material sustainability gains via the following steps;

1. Historical operational data from CSIRO's Data Clearing House trained Exergenics' plant simulation algorithms, and site knowledge was leveraged to place constraints on the model. Multiple optimisation loops were deployed to identify optimal chilled water plant setpoints for the building in a matter of weeks.
2. Exergenics' optimised setpoint recommendations were sent in a simple format to the building's incumbent BMS contractor to integrate into their existing BMS controller in a matter of days.
3. One month after implementation the savings were measured and verified against the pre-optimisation baseline.

This report dives deep into Exergenics' methodology and results.

This project was made possible by ARENA funding.

1.2 Project Context

Exergenics was engaged by CSIRO to provide chilled water plant optimisation recommendations (the ECMs) at the Synergy Building, Black Mountain facility in Canberra. The building is primarily used for laboratory and office work. This report was requested by CSIRO to measure and verify the energy and peak demand savings resulting from the optimisation recommendations.

The ECM consisted of several control optimisation strategies and were applied to the chillers and cooling towers via the BMS on January 25th 2022.

The key chilled water plant control strategy recommendations of this report are chiller staging setpoints.

1.3 Project Boundary

This M&V report is focussed on the chiller plant and dry coolers at the Synergy Building, Black Mountain, Canberra. The equipment is located on the rooftop plant room of the building. The primary chilled water system is comprised of three air cooled York screw chillers with associated primary chilled water circulating pumps and system controls.

2. Exergenics Chiller Staging App Project Knowledge Sharing Report

2.1 Overview

This report outlines the Measurement and Verification (M&V) of the Energy Conservation Measures (ECMs) that were recommended by Exergenics and commissioned by Control & Electric. CSIRO engaged Exergenics to model and optimise the Synergy Building (Building 801, Black Mountain Canberra) chilled water plant using data collected from the Data Clearing House (DCH). Modelling was carried out by Exergenics in October 2021 and the updated control strategy was commissioned by Control & Electric on January 25th, 2022. M&V was conducted by Exergenics to quantify the energy consumption (kWh) and peak demand (kVA) savings resulting from the updated controls.

The M&V methodology chosen was Option B (Retrofit Isolation) of the International Performance Measurement and Verification Protocol (IPMVP).

Key findings from the M&V are listed below:

- Energy savings: 2,049 kWh
- Carbon abatement: 1.6tCO_2e (assumes ACT grid emissions intensity of 0.79kg CO_2e/kWh)
- Cost savings: $307 (assumes blended electricity tariff of 15c/kWh)

Due to the limited amount of time elapsed since the implementation of the ECMS this report was only able to cover a 32 day period of which there was a high cooling demand for the building. Whilst the benefits of the ECM are expected to continue, the energy avoided is not expected to remain as proportionately high during lower cooling demand periods. Preliminary projections by Exergenics have shown a 1.7% reduction in energy consumption.

2.2 Baseline Energy Model

We performed regression on the chilled water plant electrical energy consumption by using the Cooling Degree Days (CDD) with a 12°C reference temperature and daily cooling demand in kilowatt refrigeration hours (kWrh). The regression yielded a strong correlation across the baseline period.

A multivariate least-squares bi-linear regression function the following model was produced:

Linear model:

$$f(x,y) = p00 + p10*x + p01*y$$

where,

f(x,y) = Predicted Daily Mechanical Equipment Energy Consumption (kWh)

x = Daily Cooling Degree Days with a 12°C reference temperature (CDD_12)

y = Daily Building Cooling Load (kWrh)

Coefficients:

p00 = 87.26

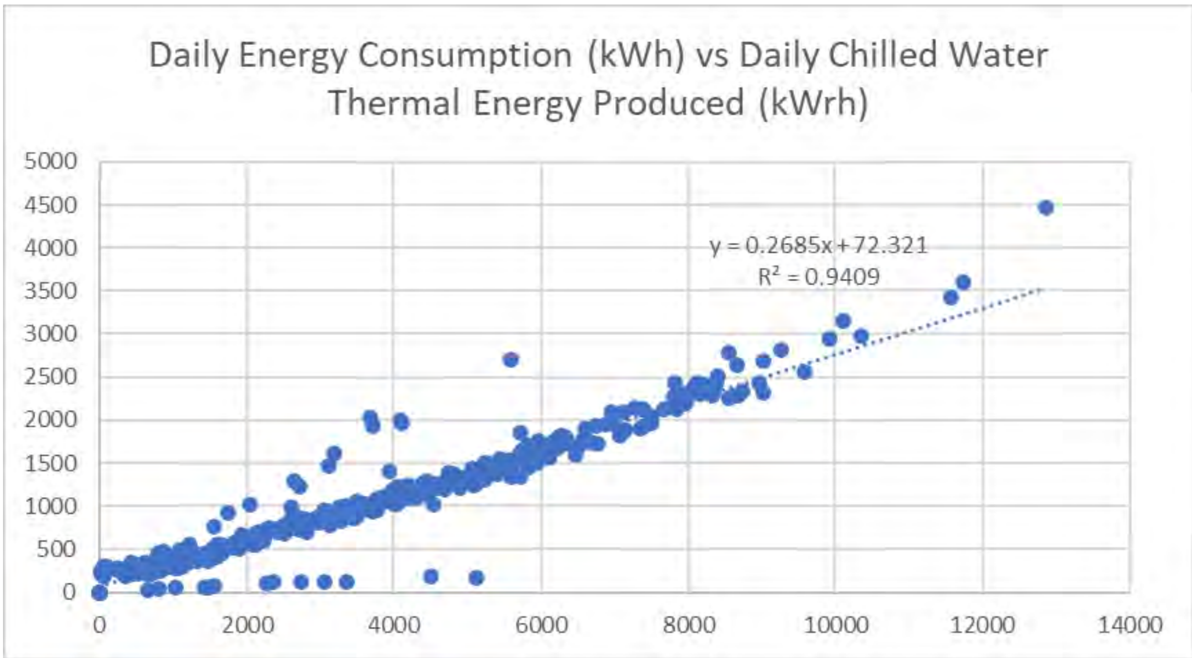
p10 = 26.90

p01 = 0.227

Goodness of fit:

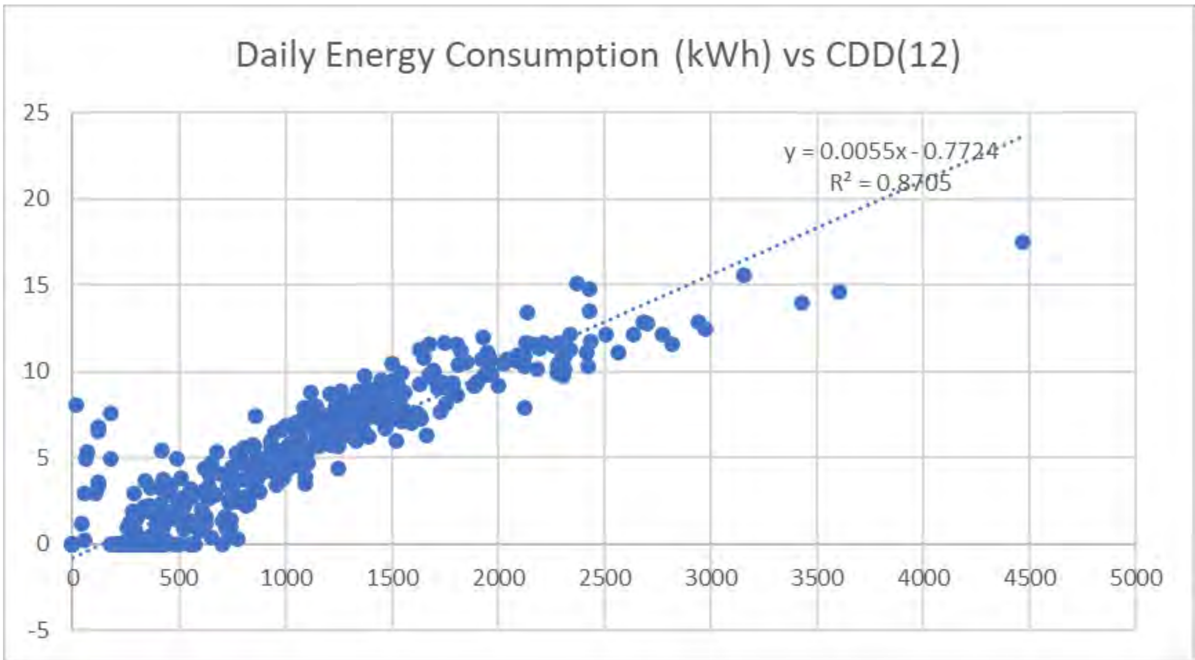
R-square: 0.94

The figure below shows the relationship between daily energy consumption and the independent variable, daily chilled water thermal energy production.



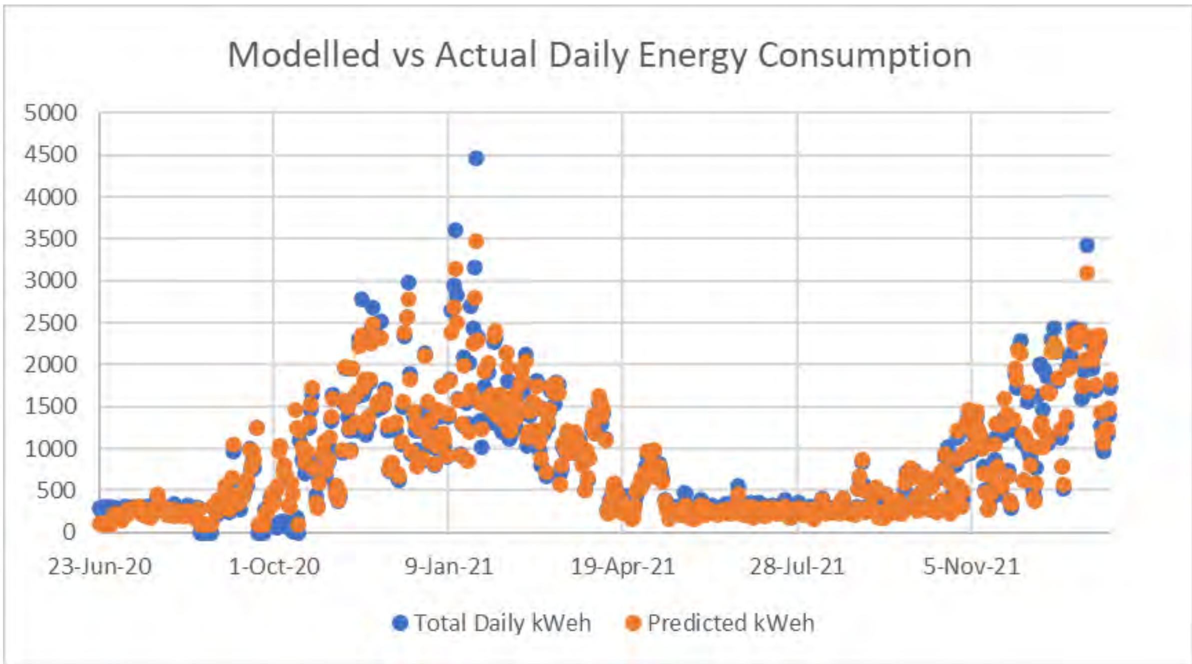
(fig 1.1 - Daily Energy Consumption(kWh) vs Daily Chilled Water Thermal Energy Produced (kWrh))

The figure below shows the relationship between daily energy consumption and the independent variable, CDD.



(fig 1.2 - Daily Energy Consumption (kWh) vs CDD (12))

The figure below shows the relationship between actual energy consumption and the regression model built from CDD and daily chilled water thermal energy production.

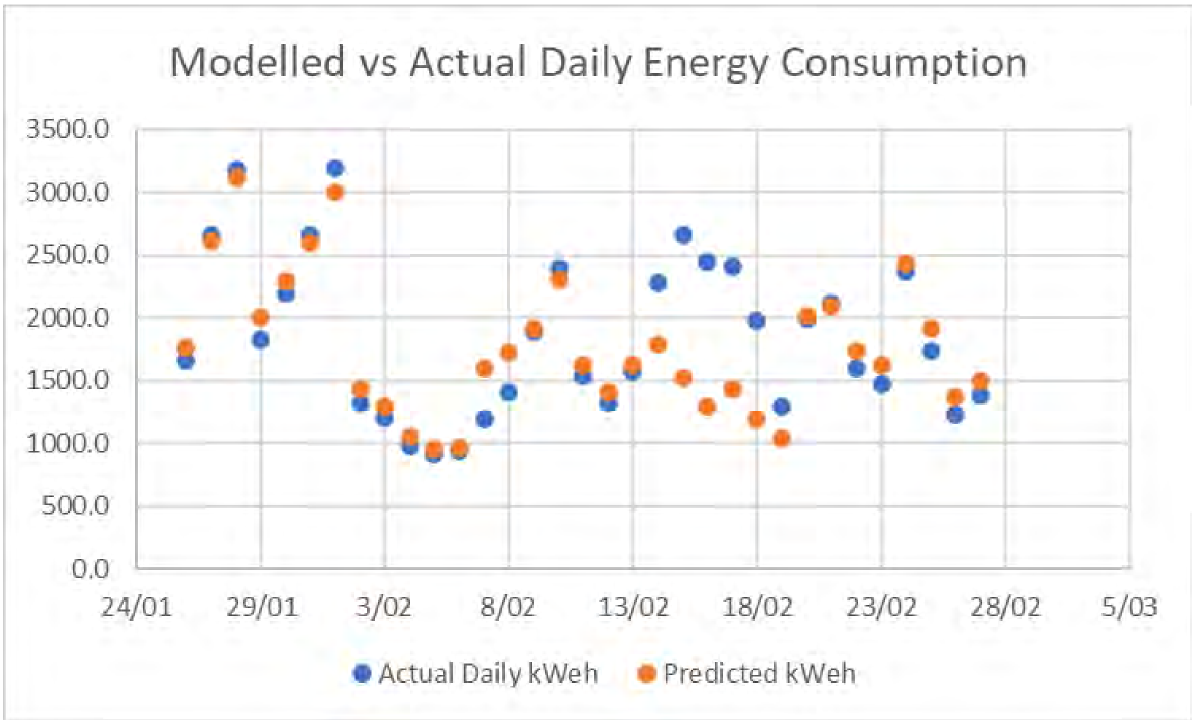


(fig 1.3 - Modelled vs Actual Daily Energy Consumption)

2.3 Reporting Period

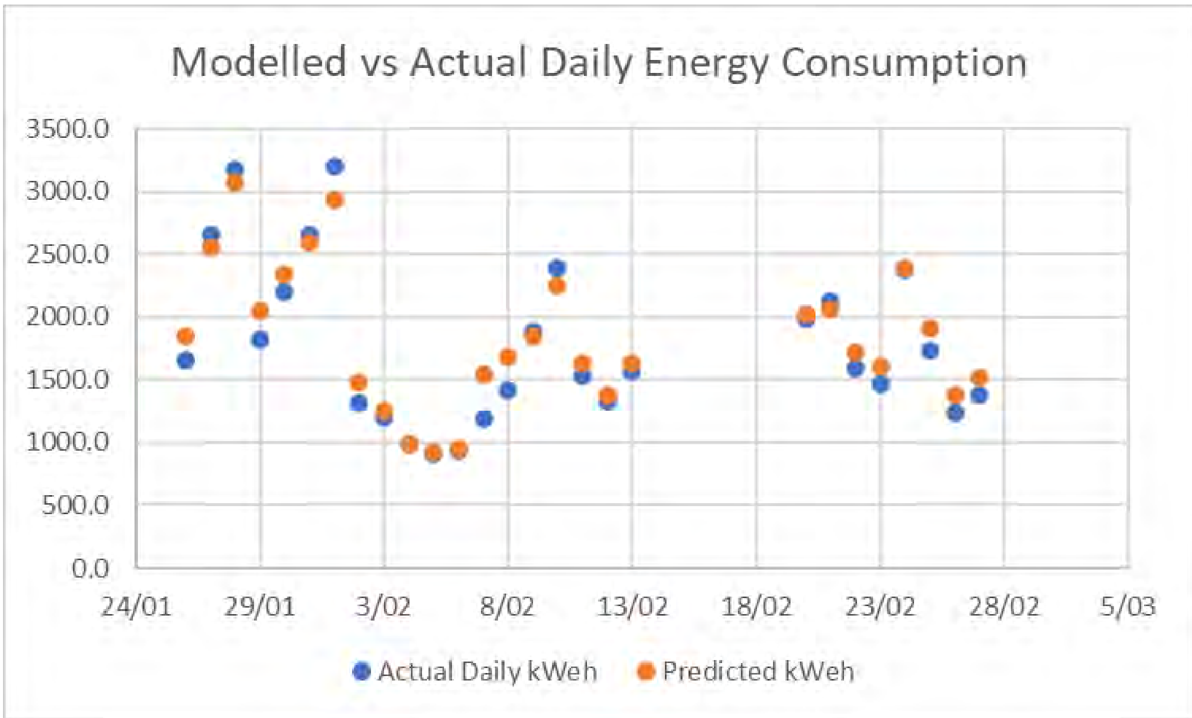
Outliers in the Reporting Period

The figure below shows the actual consumption versus the predicted (modelled) consumption. Generally there is a strong relationship between the modelled and the actual consumption - with a modest reduction in actual energy consumption overall. However there is a significant outlier period (14th -19th February 2022) which would skew the results. Exergenics has reviewed the source of these outliers and determined that those days should be excluded from the reporting period. A comprehensive analysis has been included in this report.



(fig 2.1 - Modelled vs Actual Daily Energy Consumption)

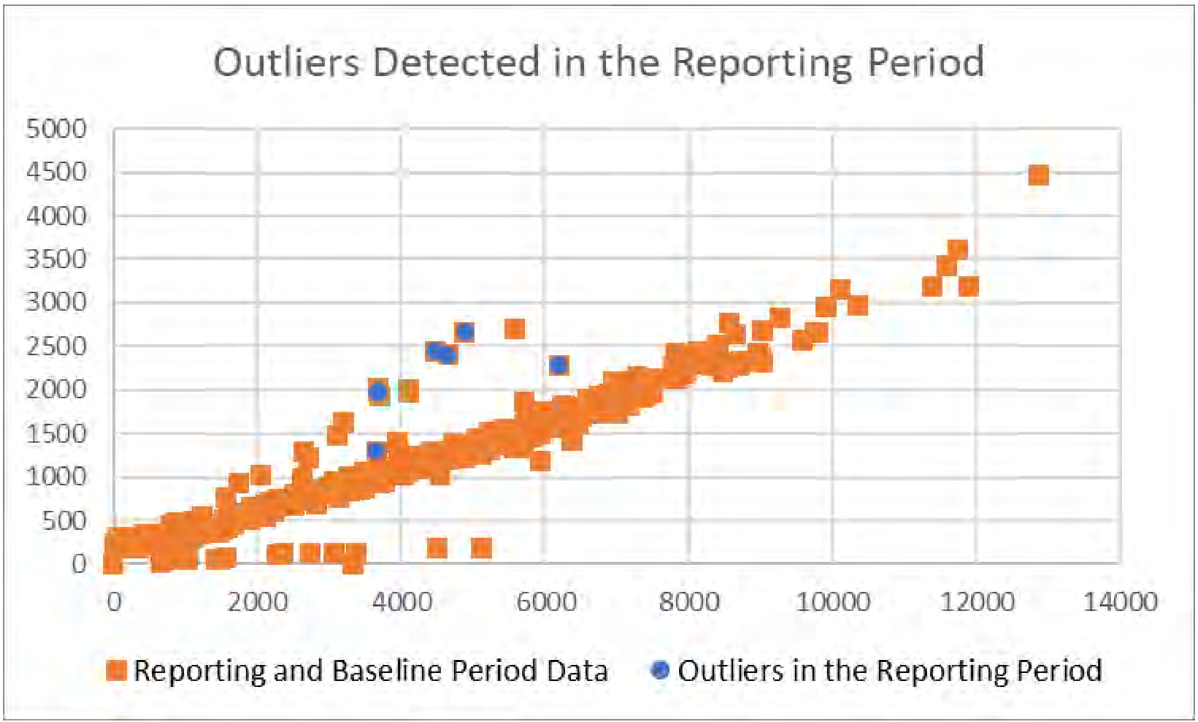
The figure below shows the same modelling, but with the exclusion of the outlier data.



(fig 2.2 - Modelled vs Actual Daily Energy Consumption, excluding outlier)

Outlier Investigation

The figure below shows 6 data points in the reporting period that were identified as unusual. Given the relatively small data set (32 points) in the reporting period versus 580 in the baseline these anomalies provided significant error in the final savings result and have been removed from the overall calculations.



(fig 2.3 - Outliers Detected in the Reporting Period)

Further analysis of the electrical metering data determined that there was an error with the data reported by the electrical meter. The figure below shows an alternative calculation of the chilled water plant energy consumption (calculated using the individual BMS points for the chillers and pumps, from the power consumption (kW) point on the high level interface for each equipment - these are compared against the energy consumption as reported by the electrical meter B801_MCC0404. There is a very strong linear relationship between the two sources, noting there were only a handful of outlier points in the dataset.

2.4 Final Results

Using the regression model developed above it is possible to predict the energy consumption of the chilled water plant after the ECMs were implemented on January 25th 2021. This was used to calculate the avoided energy consumption in accordance with IPMVP principles. The model was used to produce the table below which summarises the predicted versus actual energy consumption during the reporting period. There is a total reduction in actual energy consumption during the reporting period of 4.3%, clearly demonstrating the success of the ECM.

Totals	Values
Actual Energy Consumption (kWh)	47,934
Adjusted Baseline Energy Consumption (kWh)	49,984
Energy Avoided (kWh)	2,049
Energy Avoided (%)	4.3 %

(fig 3.1 - Results Summary Table)

3. Conclusion

A total of 2,049kWh of avoided energy consumption has been measured through the analysis described above. This represents 4.3% of the energy consumed during the reporting period. Assuming a generic electricity tariff of 15c/kWh, this represents an annual cost saving of roughly $3,907. Using ACT's grid emissions intensity of 0.79kg CO2e/kWh, this ECM also delivered a carbon abatement of roughly 1.6t CO2e.

Due to the limited amount of time elapsed since the implementation of the ECMS this report only covers a 32 day period of which there was a high cooling demand for the building. Whilst the benefits of the ECM are expected to continue, the energy avoided is not expected to remain as proportionately high during lower cooling demand periods. Preliminary projections by Exergenics have shown a 1.7% reduction in energy consumption. This report will be revisited at a later date to confirm the long term benefit of the ECMs.