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Report #LLHC4-007

Healthcare Living Laboratories: Queensland Children's Hospital – Technology Evaluation Report: Buildings Alive (Centre for Children's Health Research)

V2 - 27th May 2022

QUT

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.
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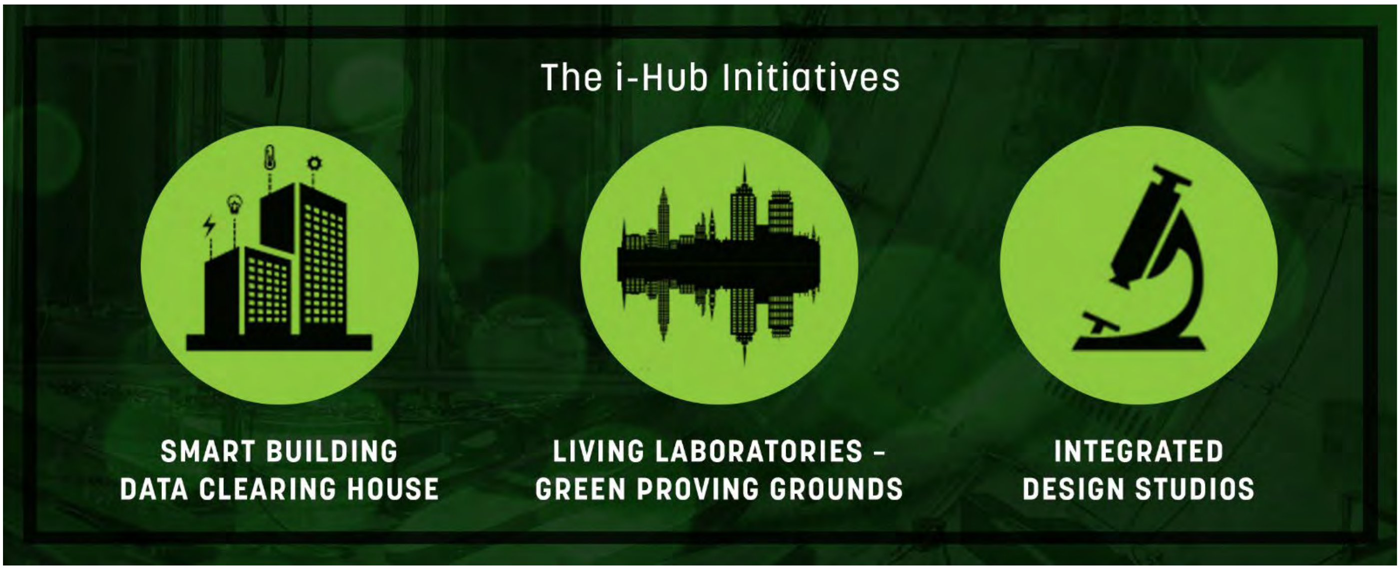

Healthcare Living Laboratories: Buildings Alive for QCH CCHR

The Living Laboratory in Queensland Children's Hospital (QCH) supports the hospital sector to transition to a net-zero energy/demand future. In particular it validates the impact of emerging technologies in demand reduction, demand management, renewable energy and enabling technologies, in terms of core health services (patient and worker health and comfort), building maintenance and operations, environmental impact and financial management (including participation in energy markets).

QCH Centre for Children's Health Research (CCHR) is a nine-storey building which unites children's health research and services with the hospital. Five levels of the CCHR are dedicated to health research spaces. Buildings Alive technology was implemented to the CCHR building in January 2022 with energy data back filled from 2019.

Lead organisation

Queensland University of Technology (QUT)

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Delta FM (QCH site principal contractor)

VERSION HISTORY

ID & Version #	Prepared By	Revision Date	Approved By	Approval Date	Reason
1.0	Aaron Liu	30/04/2022			For reviewing
2.0	Aaron Liu	26/05/2022			For reporting

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1 EXECUTIVE SUMMARY

Buildings Alive's Rapid Efficiency Feedback (REF) package which is implemented at Centre for Children's Health Research building (CCHR) within QCH precinct. The aim of REF is to enable site personnel to make changes to achieve energy and financial savings through regular feedback and continuous improvement in building performance. Figure 1 shows the concept diagram for the REF technology package.

Figure 1 Concept diagram

The outcomes of the project include establishment of energy baseline, identification of performance improvement opportunities (Section 6.1) and detection of data anomaly (Section 6.2).

Overall the building has an extremely consistent energy profile showing good, reliable automation and control. Most buildings do not have such a predictable a profile. This actually suggests that the buildings is not responding optimally to changes in occupancy and use. It would also be expected that there would be more response to weather (despite the electricity profile not including chilled water / heating water). It is recommended that opportunities for control changes be identified and tested, with the modelling / feedback now in place for results.

To mitigate microbial risks in the HVAC system, air handling units now run 24 hours per day. Increases in ventilation hours have increased total power consumption by 5-10% compared to baseline, depending on weather conditions. Further, increasing run hours overnight has increased the emissions intensity of the building. When supplied by grid power in QLD, the incoming electricity is typically cleanest in the middle of the day, when solar PV generation is highest. This change in ventilation operation is contributing about 4 tonnes of additional CO_2 emission per month. Given the increase, alternative air cleaning methods such as UV filtration may be more sustainable in the medium term.

In the 1st Quarter of 2022, CCHR used 9% extra electricity on workdays than the baseline this presents a potential saving opportunity of $5,119 and CO_2 emission reduction opportunity of 27 tonnes.

2 INTRODUCTION

2.1 Background

Energy is essential to ensure safe and reliable healthcare delivery. The healthcare industry uses a lot of energy due to the nature of its operation and healthcare needs. This energy use has impacts on both environmental and financial sustainability. Public hospital and healthcare precincts are often the largest energy user and high emitters in Australia's public service portfolio [1][2], as well as representing a major single budget portion [3].

Within major hospital precincts, there are often a range of medical facilities, healthcare spaces, research institutes, laboratories and testing centres. The Queensland Children's Hospital precinct is comprised of three buildings [4]:

- the Centre for Children's Health Research (CCHR)
- the Main Hospital (MH) Building and
- the Central Energy Plant (QCH EP) Building.

CCHR uses approximately 2GWh electricity each year and the whole QCH precinct uses around 26 to 27GWh of electricity annually based on past seven years history data. More information about QCH Living Lab's energy infrastructure and baseline data can be found in [5].

2.2 Site Descriptions

The Centre for Children's Health Research (CCHR) is a 9-storey building which unites children's health research and services with the hospital. Five levels of the CCHR are dedicated to research and laboratory spaces including:

(i) wet and dry laboratories;
(ii) a gait laboratory;
(iii) a nutrition laboratory; and
(iv) the Queensland Children's Tumour Bank, which provides a tissue repository for national and international cancer research.

The remaining levels accommodate the QCH Pathology service, office areas, facilities management staff, reception and car parking.

The CCHR building shown in Figure 2, previously also called Academic and Research Facility (ARF) building, has a total floor area of 15,201 m^2. The building has five different types of HVAC systems, including constant air volume (CAV) systems, variable air volume (VAV) systems and fan coil units (FCUs). Together, they serve 41 different heating ventilation and air-conditioning (HVAC) zones with 55 air distribution terminal units. CCHR's space cooling and heating needs are met by chilled water and heated water supply from the central energy plant.

Figure 2 Centre for Children's Health Research (CCHR)

As shown in Figure 3, the monthly electricity use for the CCHR building is fairly stable. The CCHR building used 1.96GWh electricity in 2018, 2.08GWh in 2019 and 2.11 GWh in 2020. There is no obvious electricity use change pattern across months or seasons. In another words, electricity use has been quite stable through a whole year. Please note CCHR building has its own air handling units but chilled and heating water is supplied from the central energy plant which largely explains the lack of seasonal energy use patterns.

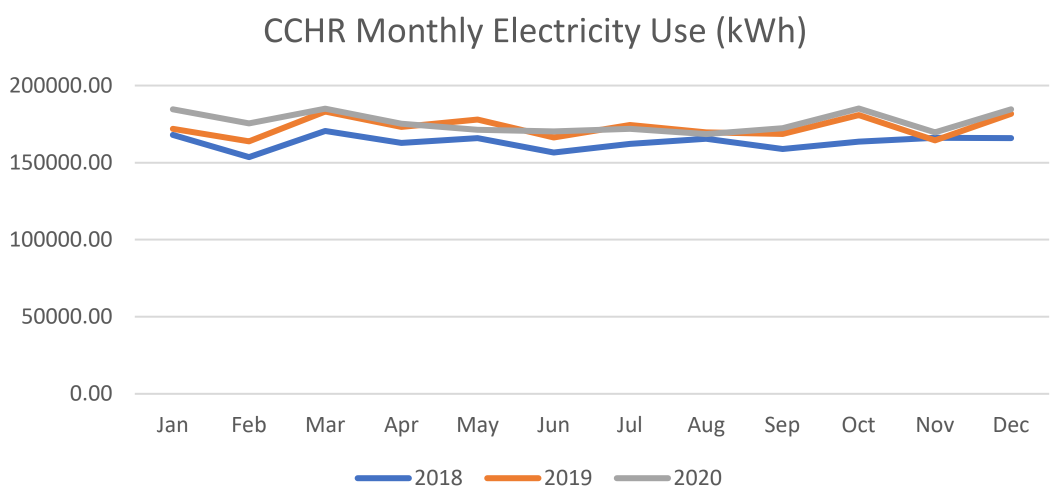

Figure 3 CCHR monthly electricity use

2.3 Technology Overview

The technology under testing is Buildings Alive's Rapid Efficiency Feedback (REF) package which is implemented at QCH CCHR building. The aim of REF is to enable site personnel to make changes to achieve energy and financial savings through regular feedback and continuous improvement in building performance. An overview of the REF process flow is illustrated in Figure 4.

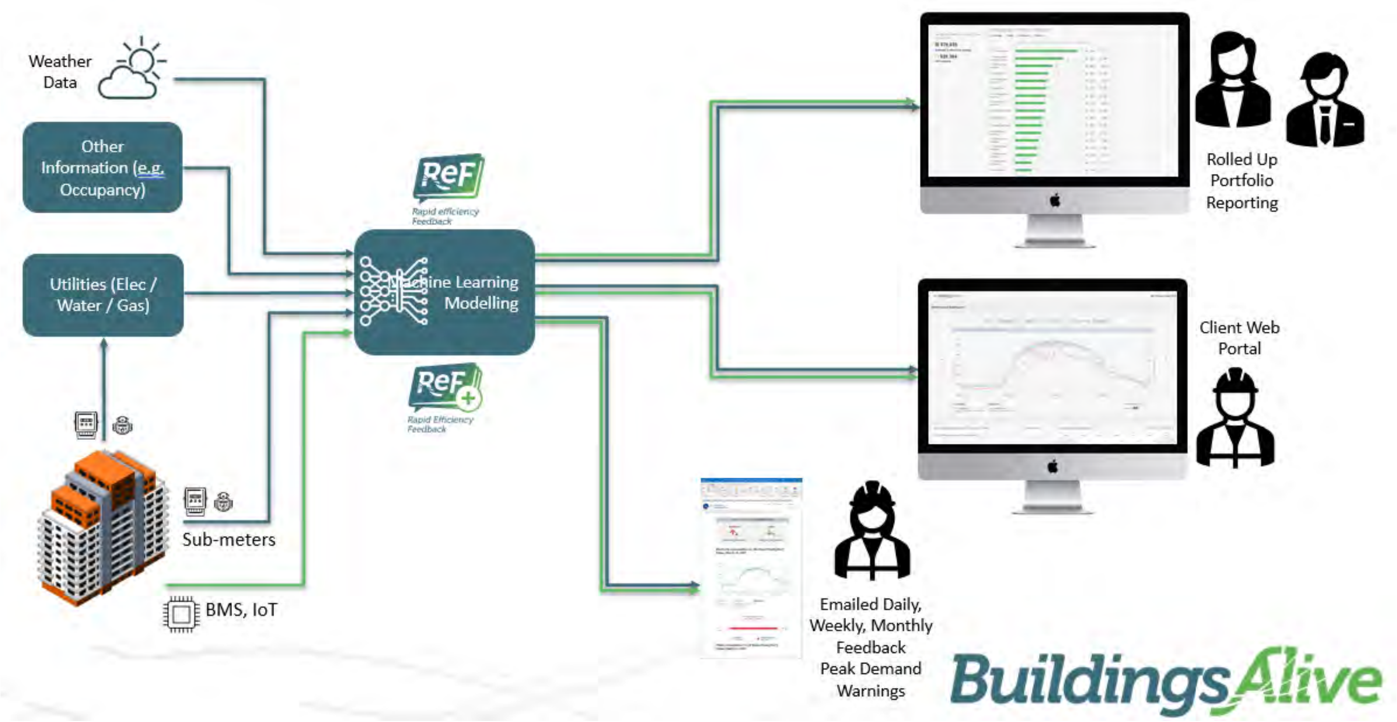

Figure 4 REF process flow overview

REF has four major processes: data ingestion, modelling, site discussions and feedback loop (Table 1).

Table 1 Buildings Alive REF processes

Step	Name	Purpose
1	Data ingestion	• Ingest historical data
2	Modelling	• Build and check models
3	Site discussions	• Identify suitable site contacts who receive energy performance feedback • Establish regular meetings
4	Feedback loop	• Building feedback loop starts to commence • Site people make incremental changes • Review results and provide updates

2.4 Objectives

The main objective of this project is testing performance of Buildings Alive Rapid Efficiency Feedback on QCH CCHR building, including performance benchmarking and data anomaly detection.

3 TEST DESCRIPTION

3.1 Tested Item Description

The technology is Rapid Efficiency Feedback package, supplied by Buildings Alive. The technology package and processes were described in Section 1.3 and provided in Table 1.

3.2 Qualification for Testing

The technology was considered as no-risk (to patients and clinicians) and aligned with the goals of the i-Hub. It was therefore evaluated as being suitable for testing in this specific Living Lab. Children's Health Queensland purchased the technology as their in-kind contribution to the i-Hub project. Their support to enable affordable and sustainable energy for healthcare is highly appreciated.

3.3 Test Suspension / Resumption Criteria

With further in-kind support from Children's Health Queensland (QCH's parent organisation), ongoing daily data collection and history data collection commenced in January 2022. There is no site access required other than toolbox meetings for site coordination. Virtual toolbox meetings were established between QCH facility management and Buildings Alive engineers.

3.4 Staffing / Resources Needs

Resource needs of this test are summarised in Table 2. For the testing, QCH has a Building Management System (BMS) and an Energy Management System (EMS) with historical data for the building. Buildings Alive has used the historical data to build and test a model.

Table 2 Staffing and resource needs

	Resources
Site history data	15min interval data delivered to Buildings Alive in a batch by QCH
Ongoing daily data feeds	15min interval data delivered daily to Buildings Alive by QCH
Modelling, establishing a baseline and operation optimisation	Buildings Alive
Reporting	QUT

The staff roles and responsibilities are provided in Table 3.

Table 3 Roles and responsibilities

Role	Responsibility
Bruce Bonney **Jason Sanders** **(QCH)**	- Living lab host and coordinator at QCH - Identification of operational staff to receive regular emails and make incremental changes - Providing historic data - Coordinating the research requirement with QUT - Reporting any problems that might hinder/stop the testing.
Mike Case **Brad Schultz** **(Buildings Alive)**	- Building a building performance model - Quantifying energy saving potential and emission reduction. - Providing training to QCH and contractors on installation/site configuration, operation and maintenance (if applicable) - Providing all required documents in Section 3.1, 4.1 of the test plan.
Aaron Liu **(QUT)**	- Project manager of the QCH Living Laboratory - Coordinating the test, writing the test report and distributing the test report according to contractual arrangement
Wendy Miller **(QUT)**	- Project Leader, overseeing the test regime and report writing / distribution

3.5 Instrumentation Plan

No specific additional instrumentation was required. The testing used data from QCH. Buildings Alive provided the computing power, relevant software and resources to build a model and applied the technology.

4 METHODOLOGY

4.1 Test Approach and Description

The complete test approach is depicted in Figure 5. The first step was to acquire data and then to ingest data. Buildings Alive engineers have done energy modelling for the building. In the fourth step, site discussions happened among QCH facility management, asset operators and Buildings Alive. Regular meetings, especially during the initial phases, were set up to discuss findings and identify opportunities.

In the last step, the building performance feedback loop commenced. The appropriate site contacts have been receiving ongoing messages and are tasked with responding to anomalies in the energy performance. Incremental improvements have been expected to show in the long term as the site team make changes.

The following key aspects have been reported:
- energy savings opportunities after the technology were implemented
- data anomaly detection

Figure 5 Flowchart for Buildings Alive at QCH CCHR Building

The above steps are summarised in Table 4. Data types are described in Table 5.

Table 4 Test stages and durations

Step	Description	Duration
1	Data acquisition	12 months
2	Data ingestion	2 months
3	Modelling	1 month
4	Site discussion	2 months
5	Feedback loop & Continuous Improvement	Ongoing

Table 5 Data description

Category	Description / Purpose	Estimated Test Date	Responsibility
Daily data feeds and historical data to Buildings Alive	Measurements: • Electricity uses for CCHR • Total cooling needs for CCHR • Total heating needs for CCHR Duration: January 2019 to present	Jan 2020 - April 2022	QCH

4.2 Excluded Items

Items specifically excluded from testing are summarised in Table 6.

Table 6 Excluded items

Item Not to be Tested	Comment
Equipment energy efficiency (such as HVAC system)	Not in the scope. Work is based on main meters to the building.

4.3 Project schedule

The project schedule is shown in Table 7.

Table 7 Project schedule

Milestone	Deliverable	Start Date	End Date
Daily data feeds	Energy data, and cooling/heating needs	14 Jan 2022	Ongoing
Historical data	Energy data acquisition	Nov 2021	April 2022
Modelling	A functional model for QCH CCHR building	Nov 2021	Feb 2022
Site discussion	Identifying suitable site people and initiate regular meetings	Jan 2022	April 2022
Feedback loop	Incremental change to site operation	Feb 2022	ongoing
Reporting	Report to AIRAH/ARENA	April 2022	May 2022

5 RISK AND MITIGATION

5.1 Test Risks / Issues

A Risk Management Plan for the QCH Living Lab was developed by QUT in consultation with QCH (LLHC4_RMP_V3). Risks associated with this specific test plan are listed below.

The application and testing of the technology is offsite and data driven so there is no risk to patients, clinicians or facility engineering team. QCH and QUT committed to ensuring that the technology testing had no impact on the hospital and provided benefits to energy, environment and financial sustainability.

COVID-19 and other health related events may result in limited or no access to the test site, at short notice. This risk was irrelevant for this technology testing.

5.2 Expected energy performance

The REF technology package does not save energy in and of itself. The intent is to create a continuous improvement loop to allow the site team to make a change, see the results and then make further improvements. Thus, it is as much a psychological tool as an engineering tool. If the feedback is not put in front of individuals with the motivation, technical capability, and approval to make changes, then it is unlikely changes will be made and improvements gained.

To mitigate this risk, QCH Living Lab host has helped to identify operational staff to receive regular emails and make incremental changes. Meetings between operational staff and Buildings Alive were scheduled to ensure project effectiveness, especially in the initial stage of the project, such as Feb to May 2022.

6 TEST RESULTS

This section presents the results for performance benchmarking and data anomaly detection.

6.1 Performance benchmarking

Performance of the building has been very consistent and mostly in keeping with baseline. Figure 6 shows a week of electricity use profile and its week day electricity uses from 28 March to 1 April 2022 were on the higher ends of base range or slightly increased from the base range.

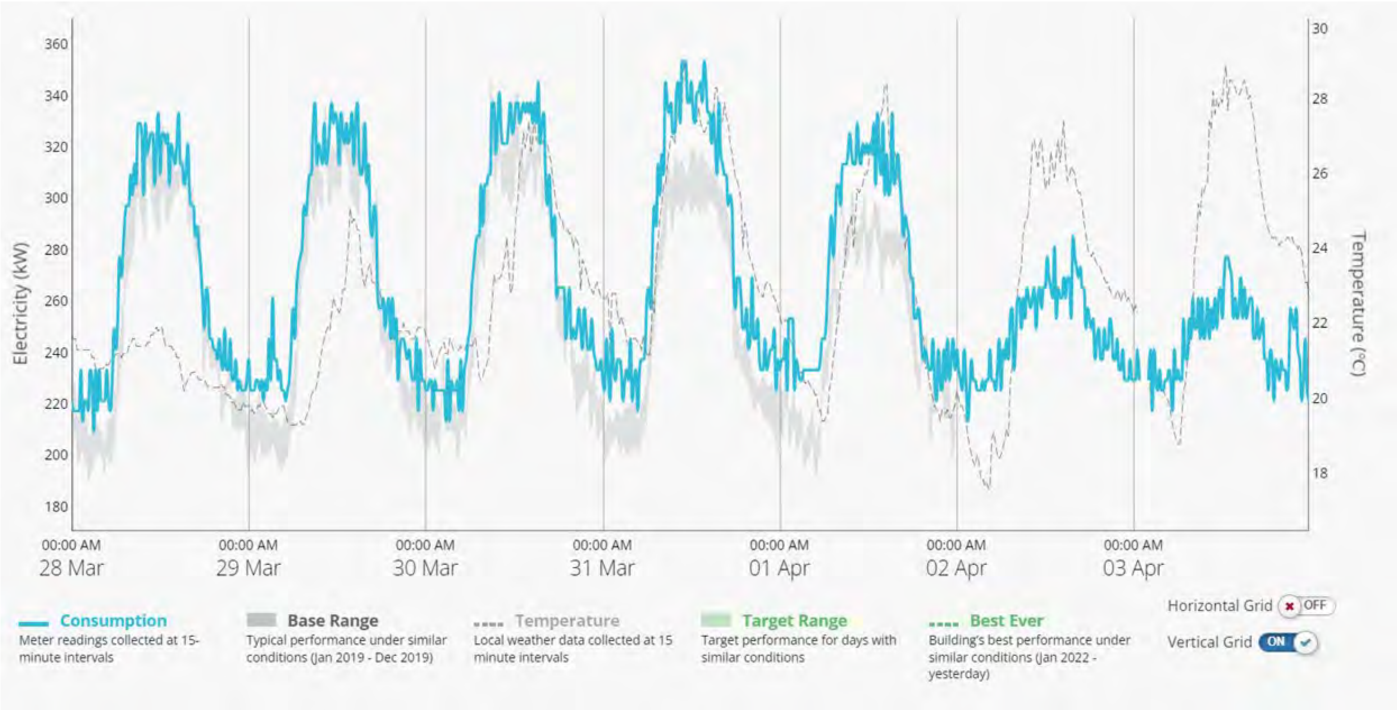

Figure 6 Benchmarking of a week energy profile

Overall Energy Performance

Overall the building has an extremely consistent energy profile showing good, reliable automation and control. Most buildings do not have such a predictable a profile. This actually suggests that the buildings is not responding optimally to changes in occupancy and use.

It would also be expected that there would be more response to weather (despite the electricity profile not including chilled water / heating water). It is recommended that opportunities for control changes be identified and tested, with the modelling / feedback now in place for results.

Chilled Water

Chilled water is also very predictable based on weather conditions (Figure 7).

Note that the profile shows temperature, but modelling is dependent on various other variables. No heating hot water use was observed during the period data was available.

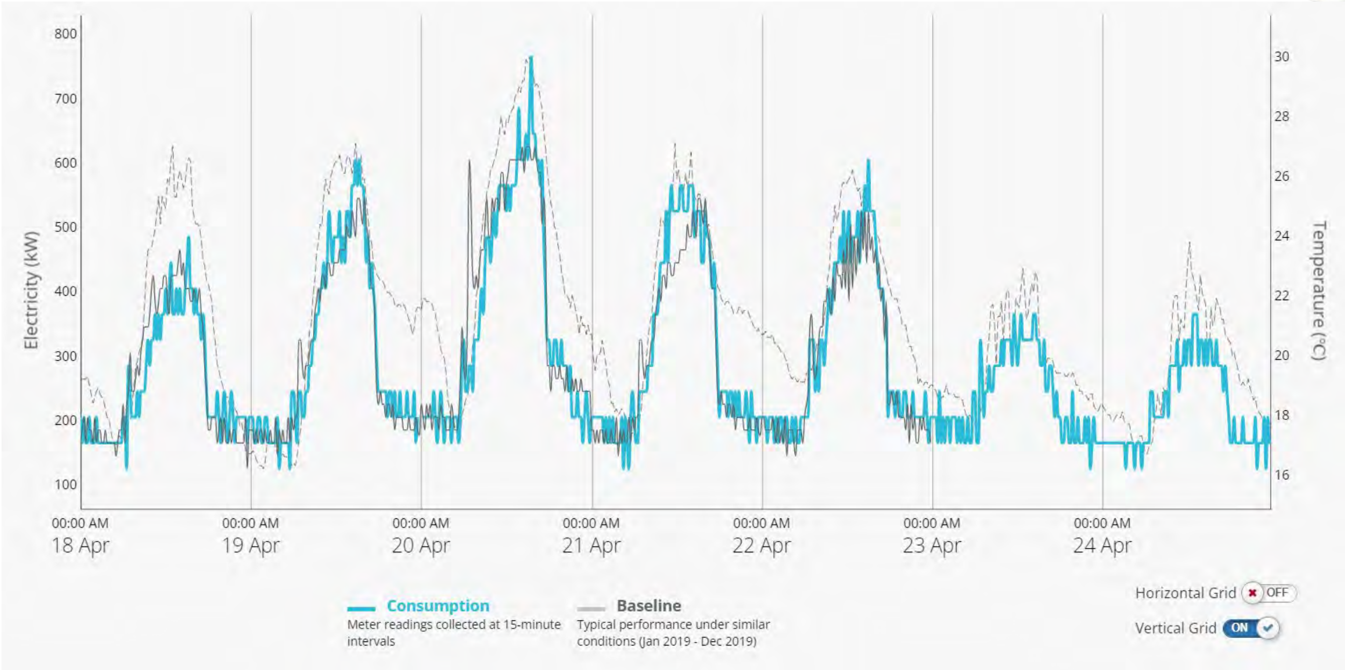

Figure 7 Energy use and temperatures

Another aspect is HVAC running longer hours. To mitigate microbial risks in the HVAC system, air handling units on the Western side of the building were changed to run at a minimum low speed outside of normal office hours to reduce the potential for mould build up in the air handling units and duct work. The Western side of the building is subject to wider weather influenced temperature fluctuations compared to the Eastern side. The increase against the pre-pandemic baseline is highlighted in light blue in Figure 8.

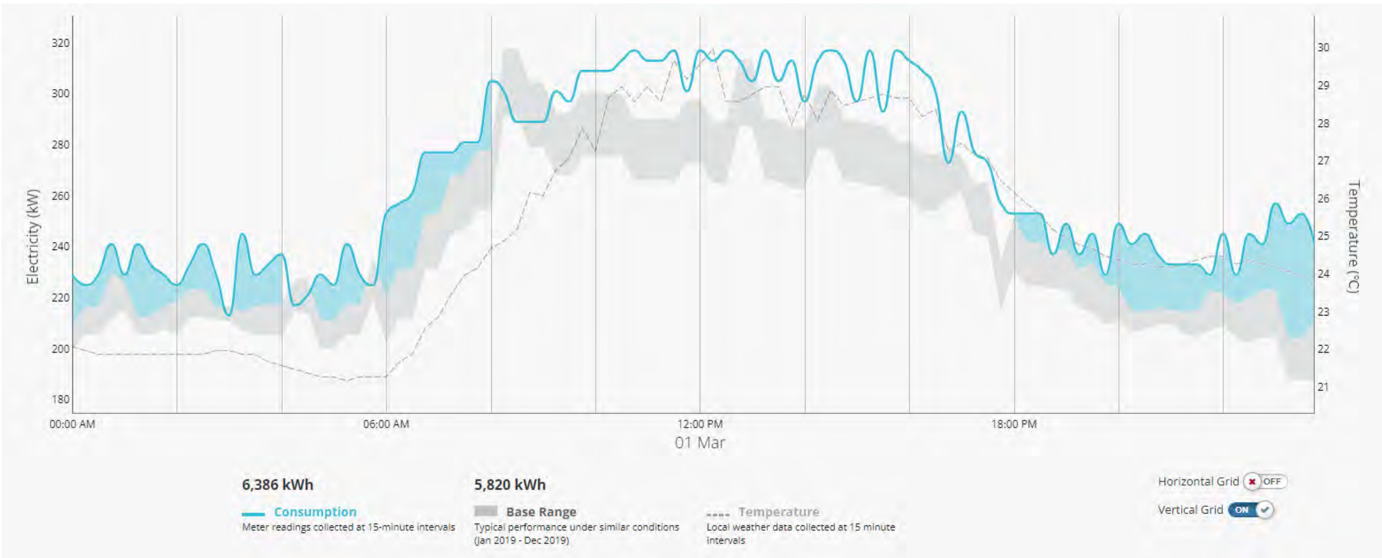

Figure 8 HVAC running for risk management

Increases in ventilation hours have increased total power consumption by 5-10% compared to baseline, depending on weather conditions (Figure 9).

Figure 9 Daily building power consumption compared to baseline

Further, increasing run hours overnight has increased the emissions intensity of the building. When supplied by grid power in QLD, the incoming electricity is typically cleanest in the middle of the day, when solar PV generation is highest (Figure 10). Figure 11 is the average daily carbon intensity for April 2022, for reference.

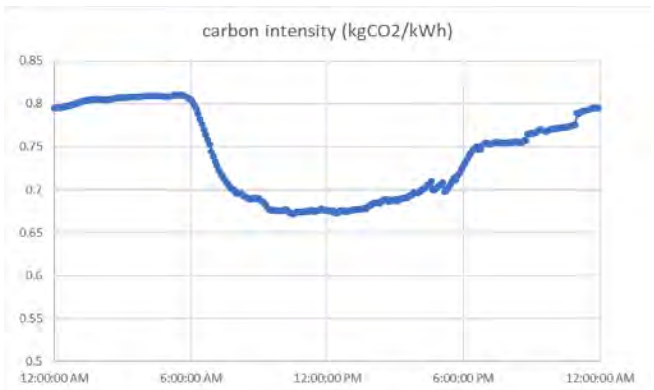

Figure 10 Carbon intensity

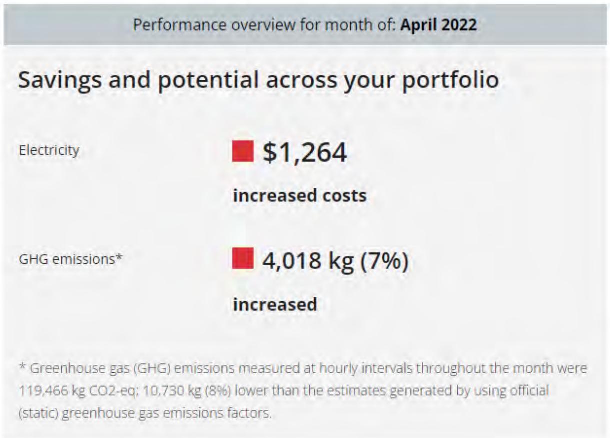

Figure 11 Performance overview April 2022

This change in ventilation operation is contributing about 4 tonnes of additional CO_2 emission per month. Given the increase, alternative air cleaning methods such as UV filtration may be more sustainable in the medium term.

In the 1st Quarter of 2022, CCHR used 9% extra electricity on workdays than the baseline as presented in Table 8. This 9% difference presents a performance opportunity for continuous improvement.

Table 8 Performance opportunities

Building	Floor area (sqm)	Saving potential (%)	Saving potential ($)	Saving potential (kWh)	t.CO2 eq potential (tCO2-e)
CCHR	15,201	9 %	$ 5,119	34,126	27

6.2 Data anomaly detection

Cross checking the electricity performance, discussion around actions taken on site revealed discrepancies. As shown in Figure 12, energy use decreased over 20% most days since Feb 2021. Further investigation revealed that one of the medium voltage meters had a current transformer (CT) which had been wired backwards during works on the main switchboard. This resulted in lower measurements than actual. This has now been corrected, which has allowed for the provision of clear, accurate energy feedback. Below shows the data before correction: each bar represents one day compared to the baseline model.

Figure 12 CCHR electricity metering 2019 to 2022 showing data anomaly due to inncorect meter wiring

7 SUMMARY FINDINGS AND CONCLUSIONS

7.1 Overall Technology Assessment

In contrast to some other digital twin and machine-learning technologies that rely on automation, the intent of Buildings Alive technology is to put daily/weekly feedback in front of those who have the ability to influence the energy performance of the building to encourage results. Due to data issues and the impact of a global pandemic, this feedback has not yet been placed in front of people who could take actions on a regular basis, so more performance results have not been forthcoming.

Figure 13 shows an engagement model which could better result in continuous energy performance improvement.

The technology remains operational at CCHR. Further work (by QCH and/or QUT) could include:

- Monitoring the effectiveness of this technology over time (energy reductions; fault detection)
- Evaluating the human resource implications (e.g. selection of the appropriate site operators and the knowledge they require to interpret results)
- Reviewing facilities management processes to ensure the nominated site operators have the authority and skills to implement changes proposed by the REF technology
- Ensuring appropriate metering and reporting to quantify the impacts.

Figure 13 An engagement model for continuous improvement (Buildings Alive)

7.2 Recommendations

The following three recommendations are made for long term continuous improvement:

- To get continuous incremental improvement over time, it is recommended to implement a site engagement model to utilise the feedback and encourage changes to site asset operation.
- Site team, ideally, Building Management System (BMS) technicians in conjunction with facility management, can make control changes, observe results on energy models and continue tuning measures to achieve iterative improvements.
- A top down approach is ideal for ensuring long term outcomes.

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