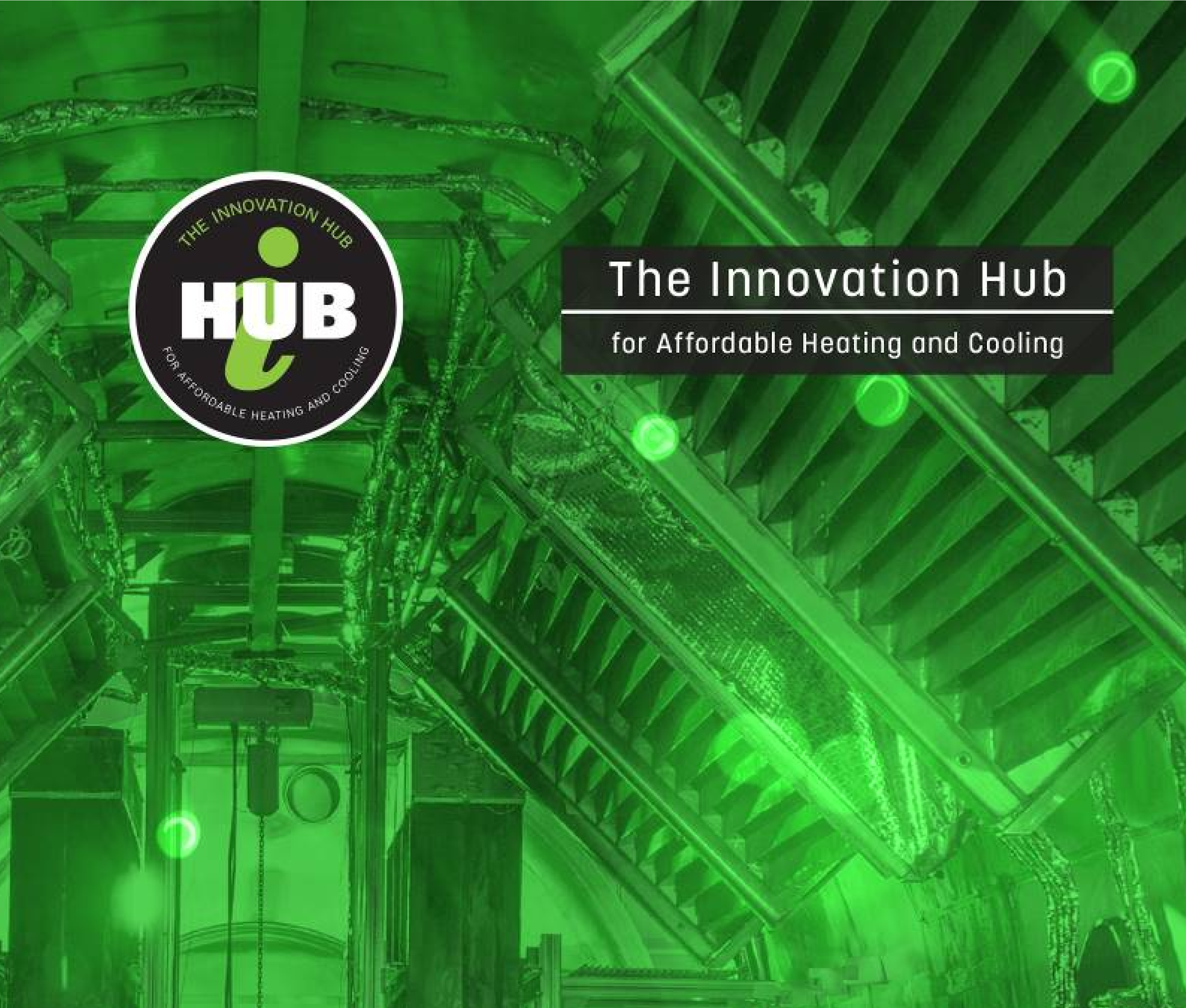


The Innovation Hub

for Affordable Heating and Cooling

Report #LLHC3-1

Healthcare Living Laboratories: Fernhill Residential Aged Care – Operations Manual and Baseline Data Analysis

V4 updated 16 October 2020

Updated sections: 2.7, 3.1, 3.2, 3.3, 3.4

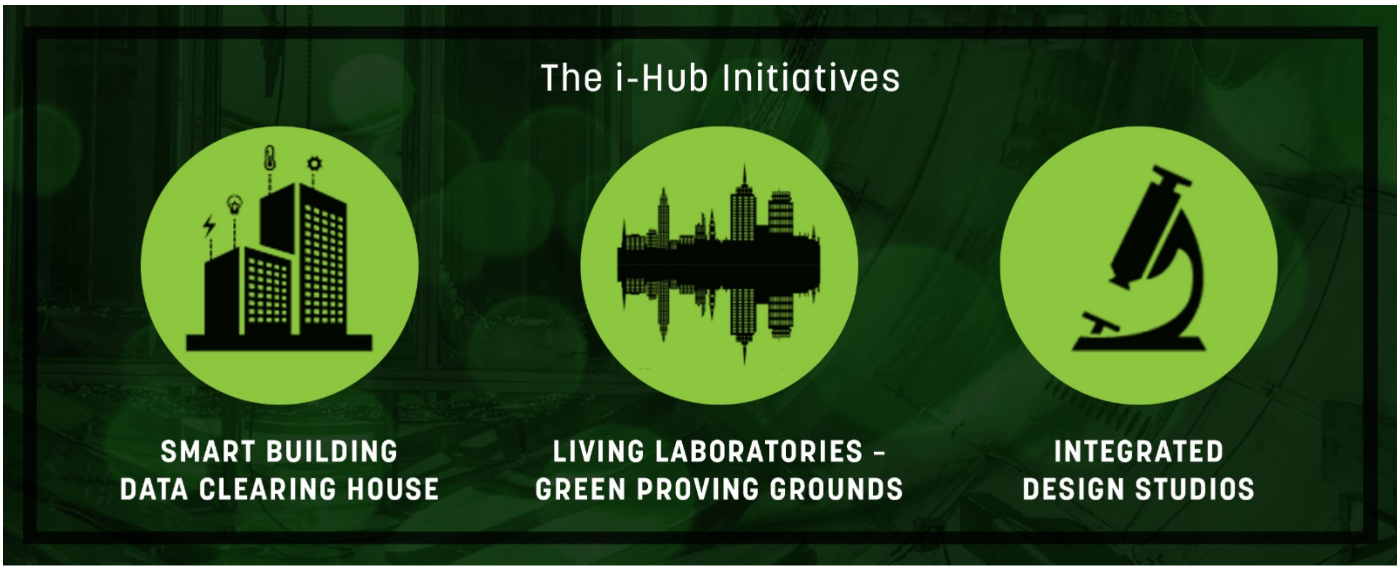
QUEENSLAND UNIVERSITY OF TECHNOLOGY

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.



Healthcare Living Laboratories: Fernhill Residential Aged Care – Prospectus & Manual

The Living Laboratory in Fernhill Residential Aged Care (Fernhill) will support the aged care sector to transition to a net-zero energy/demand future. In particular it will validate 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). An estimated 30% reduction in energy/demand (from sector wide baselines) can be achieved through the incorporation new technologies relating to HVAC efficiencies and control, demand management, grid interoperability and renewable energy into aged care policies, plans, operating manuals and procurement processes. It will not only test innovative technologies and processes but will also evaluate the usefulness of new key performance indicators (KPIs) and metrics that link energy performance (especially peak demand, renewable energy and resilience) to core health services.

Lead organisation
Queensland University of Technology (QUT)

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FERNHILL RESIDENTIAL AGED CARE LIVING LAB PROSPECTUS

This prospectus provides basic information about Fernhill Residential Aged Care precinct and its energy use.

1 INTRODUCTION

The Australian government estimates that 80% of older people will access some form of government funded aged care services before death. In 2015-16 government expenditure in this sector was $12.9 billion, approximately 75% of the total sector expenditure. Sector-wide energy consumption is dominated by space heating and cooling, hot water services and lighting (at least 65% of total energy consumption). Power (kW) and energy (kWh) are strongly correlated to outside temperature, which accounts for 80% of variation in electricity consumption. These weather-induced impacts increase with extreme temperatures.

Energy use benchmarks typically relate to occupancy levels (e.g. number of beds), although there is much variation across site. There is a need to develop more nuanced KPIs that incorporate the impacts of outdoor environmental conditions, changing society expectations of service levels with residential aged care (RAC) and electricity network operations and market conditions. In particular there is a need to understand daily and seasonal energy demand profiles of different services within RAC and the impact these demand profiles have on energy costs (for the facility), the local grid, the national electricity grid, and greenhouse gas emissions. Greater understanding in these areas can help drive investment decisions by aged care and retirement living providers and innovation diffusion by technology providers.

This project will directly address these challenges by establishing a Living Laboratory in Fernhill Residential Aged Care facility. It will enable a community of innovators, designers, researchers, practitioners and educators to test and evaluate technologies and practices to deliver greater energy productivity, reduce peak demand and explore innovative options for embedding renewable energy and storage into an aged care campus.

1.1 Bolton Clarke

Bolton Clarke is an Australian independent living and aged care service provider. The company was officially formed in 2015 when the former RSL Care and Royal District Nursing Service (RDNS) became a single organization, with origins dating back to 1885 when RDNS was established. Bolton Clarke provides aged care services predominantly in the form of retirement living communities, Residential Aged Care (all four models of accommodation) as well as Home Care visits. The company owns and operates facilities throughout Australia, with expanding offshore interests in New Zealand, the United Kingdom and China. The Australian residential facilities are predominantly located in Queensland, with a presence in most other states. The 2019 annual report indicates Bolton Clarke cared for over 3,400 residents across 25 Residential Aged Care facilities, and around 2,500 residents chose to live in 25 retirement living communities. Additionally, there were also over 3.9 million home care visits for over 52,000 clients. The company also has a Homeless Persons Program, a Veteran Family Mental Wellbeing program, and a Healthy and Active community education program. It invests in national and international corporate and research partnerships to improve health, independence and quality of life. The company's expansion plans discussed in 2019 include 450 new retirement living units and 825 residential aged care beds, predominantly around south-east Queensland.

1.2 Bolton Clarke portfolio – Energy use

Figure 1-1shows the calculated total stationary and transport energy used by the Bolton Clarke business according the 2011 National Greenhouse and Energy Reporting Scheme (NGERS) report. Electricity is clearly the predominant energy source. It is important to recognise the other primary sources (gas as well as transport fuels) because future policy changes or technology advances may mean that electricity can replace non-electrical loads, and conversely that electrical loads could be replaced by nonelectrical sources. Examples of this are heat pumps replacing gas hot water or electric vehicles replacing internal combustion engines.

A fuel source replacement may not change overall energy use, however it is noteworthy due to potential impact on building design when considering demand response integration with renewable energy, storage technologies and electricity tariffs. For example, in 2018 Bolton Clarke's vehicle fleet travelled more than 11,000,000 km. The potential electrification of that fleet could impact on the technical and financial considerations for PV and energy storage at their various RAC facilities from which their Home Care services are deployed.

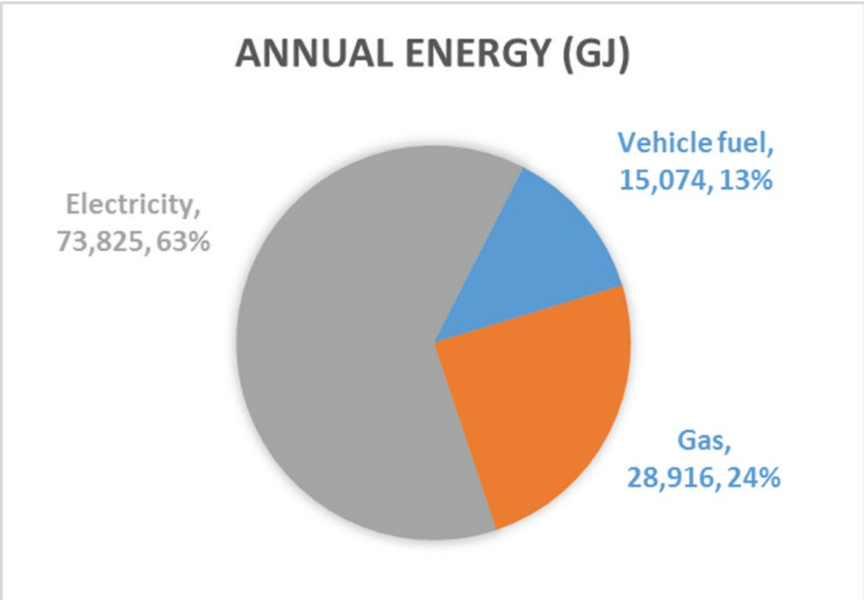

Figure 1-1 Bolton Clarke annual energy by source (NGERS report 2011)

Figure 1-2 shows the daily electricity use per bed at 23 residential aged care sites, based on twelve months of billing data. Daily electricity use varies from over 45 kWh/bed/day to less than

15kWh/bed/day[1]. Variations between sites could be explained by a number of contributing factor such as climate zone, age of the facility, construction methods and materials, kitchen services and laundry services. Without further monitoring, energy use can only be calculated on an overall 'per bed' value.

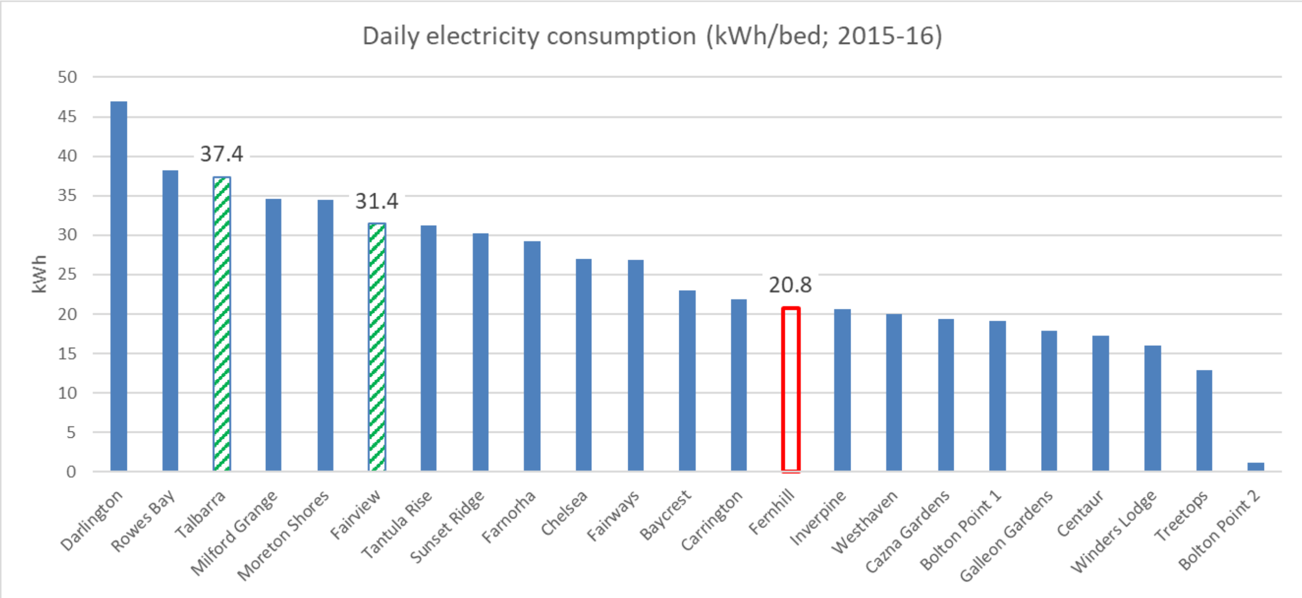

Figure 1-2 Daily energy use by site (ERM Power sites only)

The Living Laboratory in Bolton Clarke's state-of-the art new residential aged care facility (Fernhill) will support the healthcare sector in transitioning to a net-zero energy/demand future and enable the healthcare, HVAC and building services industries to validate innovations in:

- Control systems of generators, embedded renewable energy and energy storage for demand response, network services and energy market participation;
- Intelligent BMS systems with self-learning to respond to changing building usage, equipment performance, environmental conditions and electricity network requirements;
- eMobility services for in-house and community home care services; and
- Smart sensors and controls that respond to the health requirements of individual occupants.

Outputs from this Living Lab will feed into the iHUB's Healthcare Sector Wide project (LLHC1).

[1] Bolton Point 2 is considered an outlier given there are two meters at this site. Bolton Point 1 consumption is ~20kWh/bed/day, which aligns with many of the other sites.

2.1 Fernhill site and development plans

Fernhill is a residential aged care facility (RAC) and retirement village (RV) on freehold property located at Caboolture, approximately 42 kilometers north of Brisbane's CBD. The RAC on the 6.6 hectare site (Figure 2-1) consists of a 50 bed nursing home (twin and triple share rooms with shared bathrooms) and eight hostel cottages containing 114 single ensuite bedrooms (including 28 intensive care rooms). The site was earmarked for development because the spread-out nature of the hostel accommodation did not permit efficient staffing or facilitate the best possible level of care, and the shared bed wards and bathrooms of the nursing home did not meet the company's standards or community expectations. The Retirement Village comprises 87 independent living units.

Figure 2-1 Fernhill site before development

A multi-staged site development plan, as shown in Figure 2-2 , is expected to include:

- A new 162 bed multistorey RAC with communal facilities, allied health spaces, landscaped outdoor activity spaces and basement care parking. Once completed, the existing nursing home will be demolished.
- Construction of 65 supported living apartments (SLA) – sometime post 2020.
- Construction of multistorey SLAs, independent living apartments, student accommodation, retail and commercial facilities (sometime post 2030).

Figure 2-2 Multi-staged site development plan

2.2 Fernhill Residential Aged Care – new building

An artist's impression and BIM model of the new building are shown in Figure 2-3 and Figure 2-4.

Artist impression of the main entrance and porte-cochere

Artist impression of the activity area on ground floor

Artist impression of the rear communal garden and park

Artist Impression of alfresco area on the ground floor

Figure 2-3 Artist impression of the new RAC

Figure 2-4 BIM model of the new RAC

This building comprises of

- 144 bed RAC across 4 levels; 36 beds per floor; all rooms have ensuites and are either 26m^2 (standard) or 35m^2 (accessible rooms and premium rooms)
- 18 bed memory support unit
- Resident facilities (café, day spa, library, wellness centre, reflection room)
- Communal dining and sitting areas on each level
- Reception area and staff, management, training and consultation rooms
- Commercial kitchen and laundry to service this RAC and future SLAs
- Workshop, loading dock and ambulance bay
- Basement facilities: 57 bike end-of-trip facility and 46 car parks
- Day Therapy Centre and Day Care area
- Café / Retail space (for residents, family and visitors)

The building is a ‘W’ shape, with good solar access (equatorial facing) and access to prevailing north-easterly cooling breezes (Figure 2-5).

Figure 2-5 Typical RAC floor – levels 3-5, with ‘living lab resident rooms’ circled

The facility is currently under construction, with completion expected in July/August 2020. Current nursing home and hostel residents will move into the new building on completion. As the new building will accommodate the same staff and resident cohort, ‘before and after’ precinct energy measurement comparisons will be directly related to the new building, its energy systems and its operation.

2.3 Energy efficiency and ecologically sustainable design features

The RAC incorporates a range of design, construction and fit-out options to enhance energy efficiency, reduce environmental impact, enable control of energy demand, and allow for future use of renewable energy. These features include:

- Hybrid building design, enabling both natural ventilation (NV) and mechanical heating, ventilation and air-conditioning (HVAC)
- Centralised chilled water system
- Air tight building envelope
- Ceiling fans and operable windows in all occupant rooms
- Infrared sensors in all bathroom exhaust fans

- A dual hot water reticulation system
- LED lighting, with motion sensors in common areas, amenities and circulation spaces
- A Building Management System to control internal HVAC and lighting systems, and monitor energy use. Sub-metering provided for lighting, general power, hydraulics, HVAC, lifts and loads over 100kVA.
- Provision for future renewable energy generation and power factor correction

These systems, as relevant to the Living Lab, are described in more detail in the following sections.

2.4 HVAC plant

The HVAC of the RAC is a chilled water system with a peak design load of 1860kWr. The peak summer cooling load for residential rooms is estimated at 950kW. The nominal room temperature range at point of control is 22 – 25 °C dry bulb.

The HVAC system consists of three air cooled chillers (electrical dual screw type): 2 at 475kWr and 1 at 950kWr (Figure 2-6). This provides a wide range of flexibility in meeting the seasonal cooling load. The system includes 3 variable speed chilled water pumps, and 3 variable speed heating water pumps for outside air preconditioning for the air handling units (AHUs). Two water storage tanks provide thermal inertia for stable chiller control: 10,000 litre chilled water tank and a 5,000 litre heating hot water buffer tank. Variable speed secondary chilled water pumps and pipework reticulate chilled water between the plantroom, fan coil units (FCU) and outside air AHUs.

Figure 2-6 HVAC system chillers

The AHU provides dedicated chilled water, via FCUs, to each bedroom and common area. Electric heating is provided for each bedroom through the FCU. The pre-conditioned outside air from the AHU provides makeup air for toilet exhaust, winter heating and floor trim heating. Supplementary cooling and thermal control from recycled air systems are provided through the ducted FCUs.

2.5 Electrical services

The mains electricity connection has been designed to meet maximum demand (based on AS/NZS 3000 calculation, not on historical data) + 25%. Sub-mains are also required to have 25% spare capacity based on maximum demand.

The existing backup generator will be relocated to provide back-up power to the new RAC. A load shedding system will be implemented to disconnect non-essential loads in the event of a main outage. Resident rooms have essential and non-essential power outlets. Cooling loads in resident rooms are treated as non-essential, however cooling loads in common areas are treated as essential, enabling management to move resident beds to common areas if a power outage coincides with a heat wave event.

A 20kVA 3 phase uninterruptible power supply (UPS) is provided to back up communications, security and nurse call systems. UPS batteries are provided to supply 10 minutes of full load autonomy to ride out the gap in supply between the loss of mains power and the connection of generator-backed power.

2.6 Monitoring and metering – general

Sub-metering is provided for lighting, general power, hydraulics, HVAC, lifts and loads over 100kVA, as well as to any areas that are expected to be tenanted. Meters measure energy use (kWh), power (kVA, kW, kVAr), current (A), voltage (V), power factor and harmonic distortion. The Living Lab project has provided additional meters for the chilled water system, to enable measurement of thermal energy.

A Building Management System (BMS) has been designed by Systemax with the primary purpose of (a) providing a tool for the building manager and maintenance staff to interrogate and operate plant; and (b) controlling and monitoring various air conditioning plant, chiller water plant, and supply and exhaust ventilation fans, and (c) monitoring various miscellaneous alarms and data points. The BMS uses WebCTRL software and Automated Logic sensors. It transfers and receives data via the BACnet communication protocol. The Living Lab project will utilise this system.

In addition, the Living Lab project is providing a weather station (Figure 2-7) that will integrate with the BMS and be used for research and building operational purposes. This wireless, solar powered weather station (Vantage Pro2 Plus) will provide data on temperature, relative humidity, barometric pressure, solar radiation, rainfall, rain rate, wind speed and direction, as well as calculated data (evapotranspiration, heat index, wind chill). QUT will also be providing an outdoor air quality sensor (Koala Sensor) to monitor atmospheric carbon monoxide (CO) and particles (PM2.5).

Figure 2-7 Weather Station

2.7 Monitoring and metering – occupant rooms

The i-Hub Living Lab project has taken the opportunity, during the construction phase, to add additional monitoring to enable a range of technology and enabling services to be tested at Fernhill. In addition to whole building / site activities, a number of 'technology evaluations' are expected to be undertaken in resident rooms. A set of 6 rooms in the NW wing of the building has been selected as the 'living lab resident rooms' (Figure 2-6). As each of the floor plates are exactly the same, monitoring the same set of rooms on each of 3 floors allows for products to be tested on one level and simultaneously compared with the 'control' rooms above and below. These rooms were specifically selected to encompass west, north and east orientations (the orientations most affected by solar radiation).

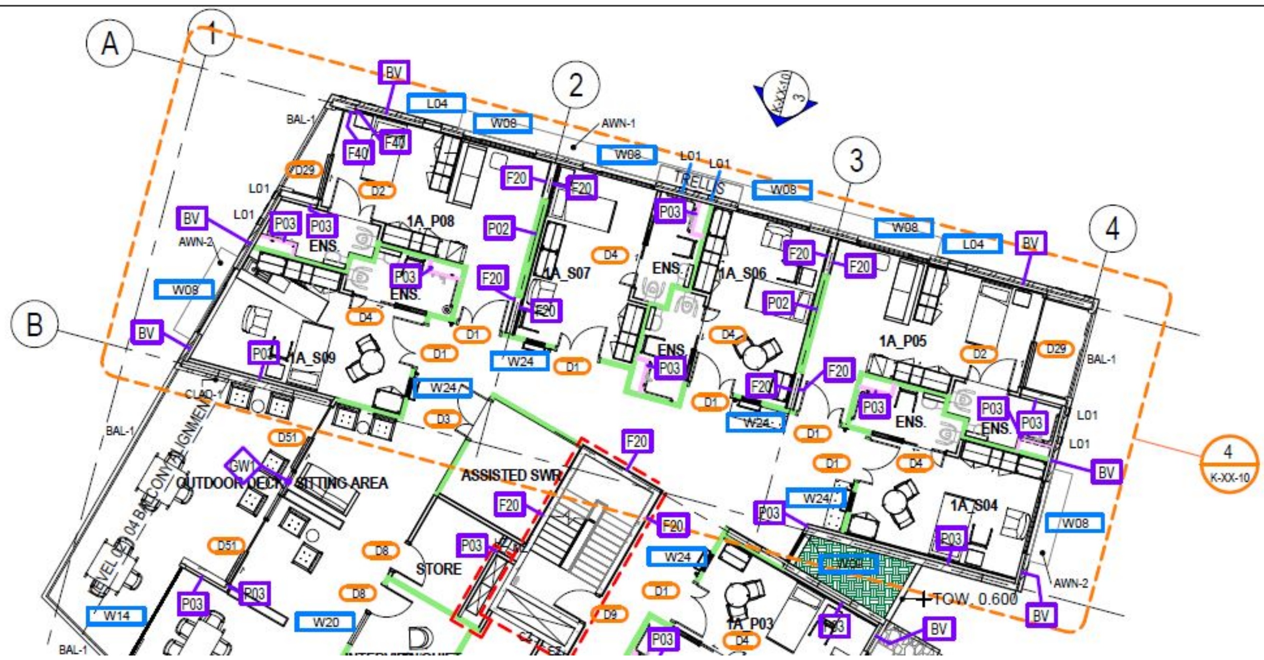

Figure 2-8 Plan view of the NW 'living lab resident rooms'

In order to achieve this 'laboratory' testing, additional monitoring has been installed in the selected rooms:

- Automated Logic sensors (ZS20-HCM-ALC) to measure temperature, relative humidity, CO_2 and motion, connected to the BMS;
- Wiring to enable for the installation of reed switches on openable windows (louvre type) and possible future connection to the BMS for FCU control;
- Steinel True Presence sensors (six rooms, one level only) to measure presence/movement, brightness, temperature, relative humidity, air pressure, VOC and CO_2;
- Netatmo indoor air quality sensors to measure temperature, relative humidity, CO_2 and sound; wireless; a 'check' measure to the other sensors.

Post-occupancy evaluations will be part of product and service testing. A bespoke Indoor Environment Quality Mobile Cart will be built to ASHRAE standards, to enable measurement of air temperature, air velocity, black globe temperature, illuminance and CO_2 in a range of locations across the facility.

Additional metering and monitoring devices will be installed on an ‘as needs’ basis, for each technology or service being tested.

In addition to metering, building performance tests will be conducted to determine the actual quality of ‘as built’ conditions in comparison to ‘as designed’.

An Airtightness (blower door) test has been performed on level four of the building to identify the actual air changes per hour and locate the leakage areas in the envelope. The results of this test will be used as the baseline, to be compared with the airtightness of the building after improved building sealing solutions are incorporated. The actual airtightness will also be used in the energy model to simulate its impact on energy consumption. More details about this test can be found in the baseline data analysis section.

Quality of the building envelope will be tested through installing temperature, heat flux, and humidity sensors to collect short period data that can be used to determine the baseline for building envelope thermal resistance. This baseline can then be used to determine the improvement resulting from using certain technologies.

Indoor air quality testing will be executed to identify the nature and quantity of any volatile organic compounds (VOC) existing in the building as a result of the new construction. Another VOC test will be made after 6 months of building occupation to identify the impact of occupants on VOC levels.

3 SITE BASELINE ENERGY DATA

3.1 Site energy composition and usage

As the RAC building is still unoccupied, the baseline energy for this site will initially be from the existing RAC facilities, i.e. the nursing home and hostels. Figure 3-1 shows the average daily energy use, per month, throughout the year at the current Fernhill RAC. As site daily activities are similar throughout the year, monthly variations can be attributed to air-conditioning loads in line with seasonal temperature variations.

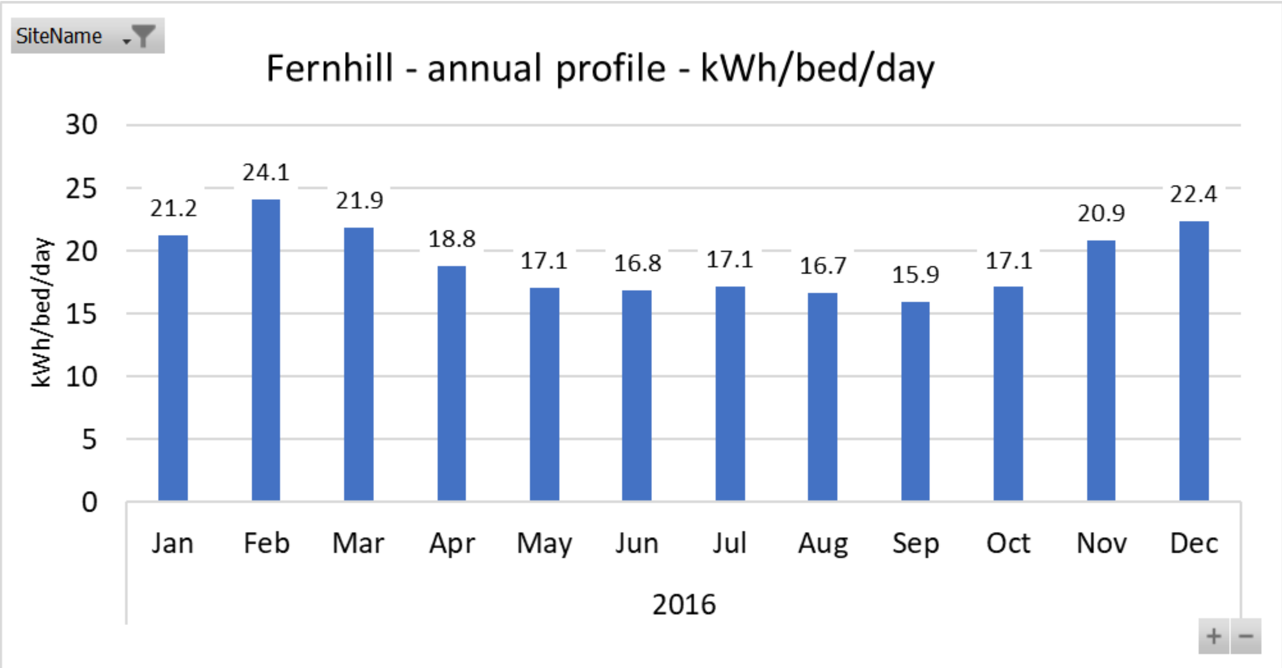

Figure 3-1 Fernhill energy consumption by month (2015-16 data)

Figure 3-2 shows several years of data, allowing patterns to be seen, such as the seasonality of the monthly average of daily energy use profiles. The main differences between years are during the late summer months (February and March), likely due to weather patterns. The winter months consistently show lower daily consumption, which is likely due to reduced air-conditioning loads during these cooler months.

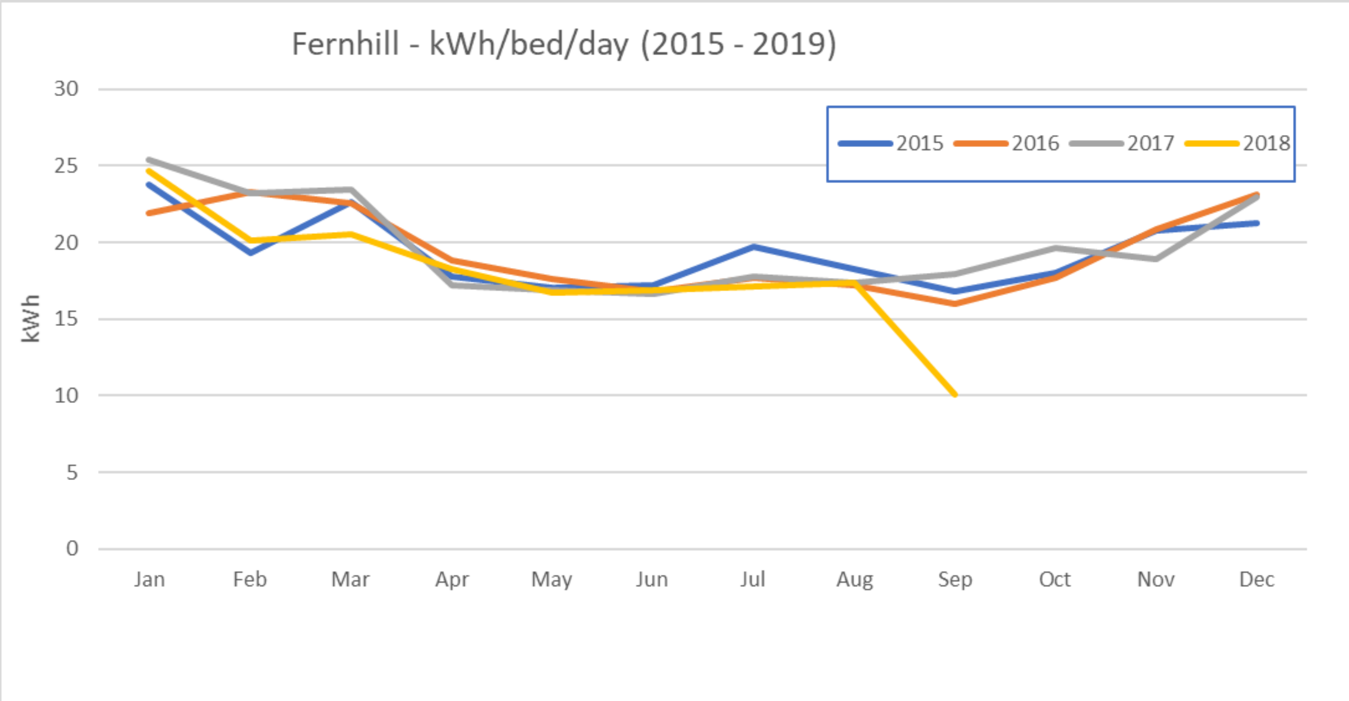

Figure 3-2 Daily per bed electricity readings by month 2015 – 2019, Fernhill Living Labs site

The average daily energy use profiles, however, are not granular enough to determine when the peaks occur. When considering peak demand, time of day is an important consideration for both load identification and assessing the potential suitability of renewable energy input. Figure 3-3 and Figure 3-4 show the daily profile for the 2018 summer and winter days which incurred the peak demand charge. The summer peak likely coincides with the hottest part of the day, and possibly lunchtime kitchen activity.

The typical summertime peak, not surprisingly, occurs during the time of highest heat load. This peak, or load levels near the peak, are maintained for several hours. The significance of this is to appreciate that interventions (embedded generation / storage or load shedding) should be designed to have enough capacity to meet both power (kW) and energy (kWh) requirements to meet a peak reduction target. The peak winter event day shows the peak occurs early in the morning. The variation in timing of peak events may mean that solutions for renewable energy integration may need to be adjusted or optimised seasonally. The shorter peak duration, compared to the summer peak, is also of interest.

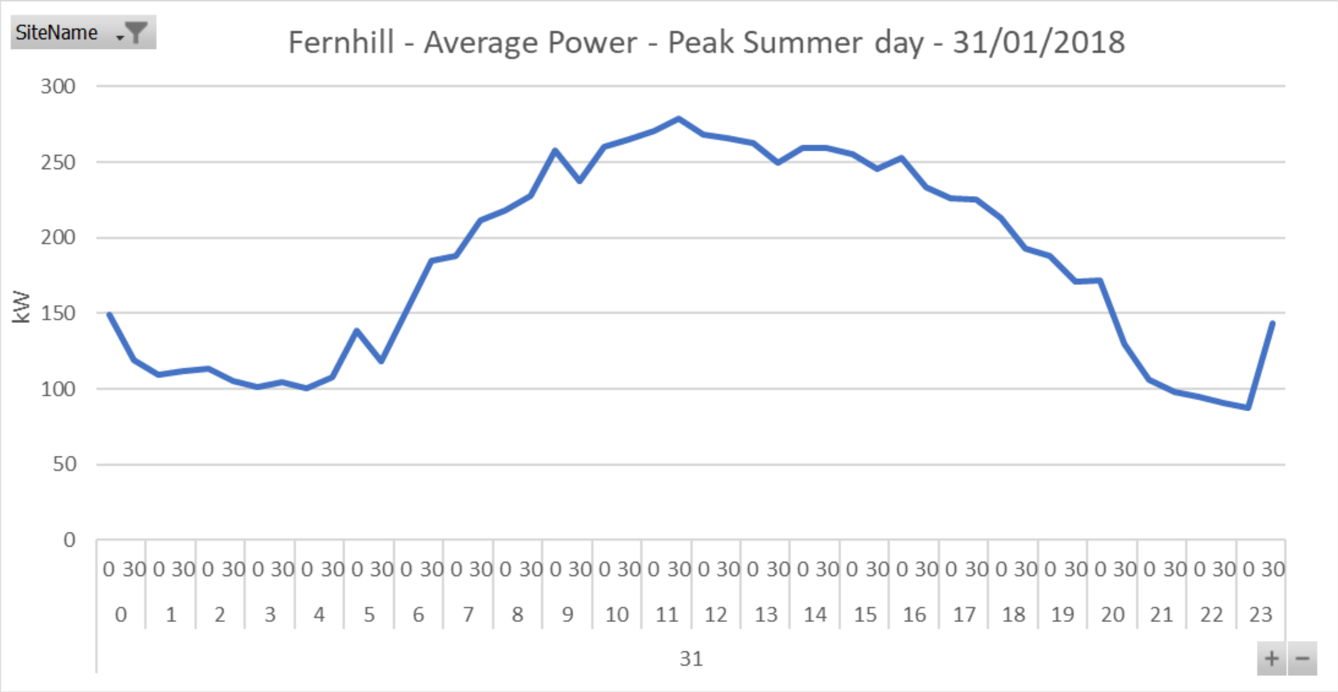

Figure 3-3 Fernhill summer daily electricity profile

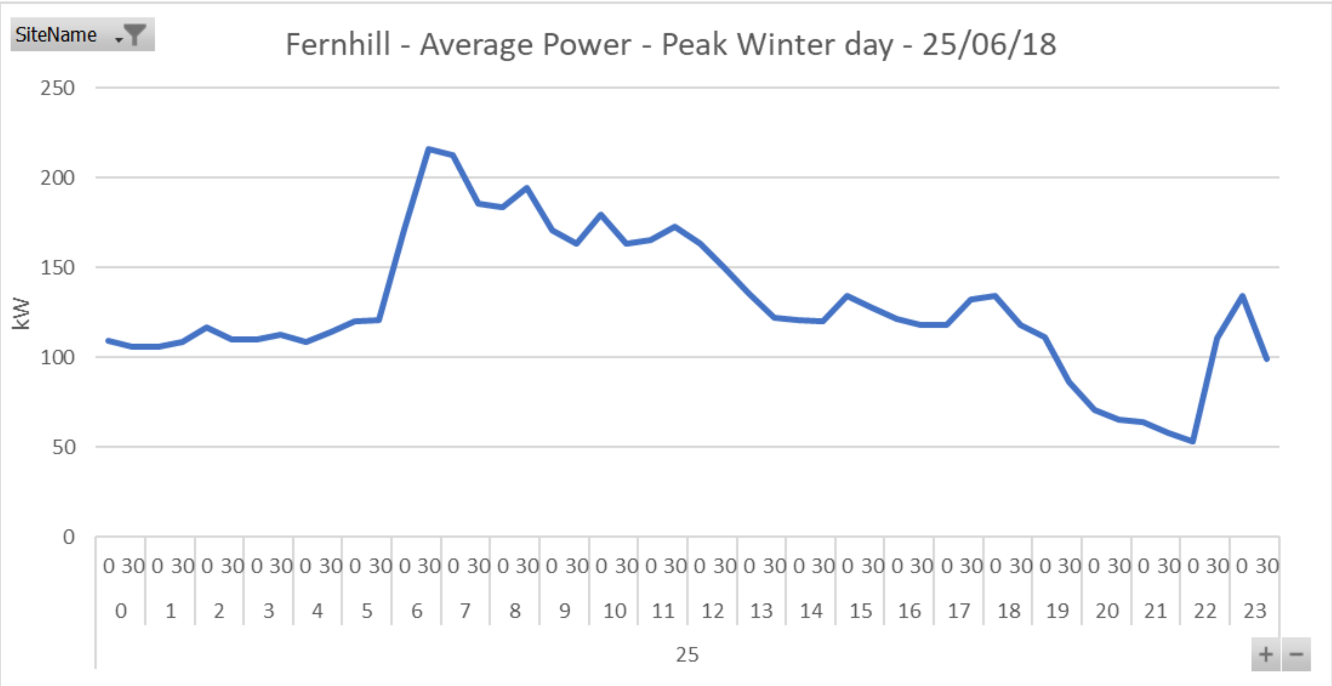

Figure 3-4 Fernhill winter daily electricity profile

Figure 3-5 and Figure 3-6 compare temperature to energy use patterns of years 2019 and 2020. The graphs show that energy use follows temperature patterns, indicating that the majority of energy consumption is for heating and cooling purposes. Energy use in summer is almost the double of energy use in winter. Energy use drops during winter when external temperature is between 15 to 20 degrees, it however rises when the temperature dops below 15 degrees. This highlights that reliance on air-conditioning during winter is less than in summer despite having temperature below the comfort threshold.

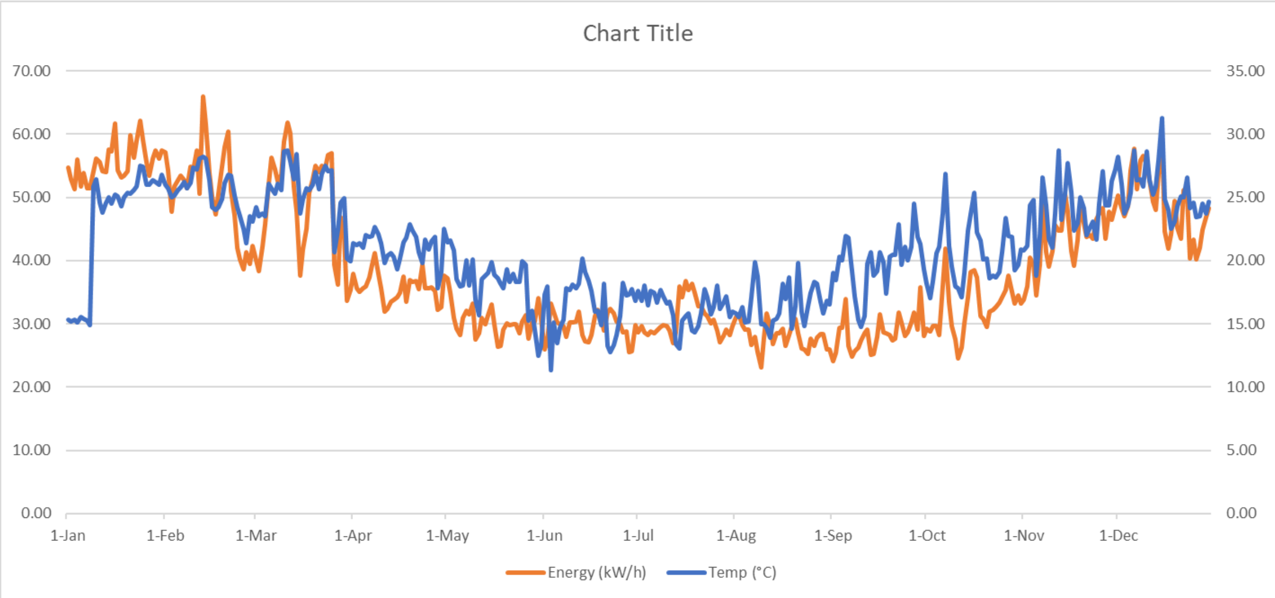

Figure 3-5 Daily temperature vs Energy use 2019

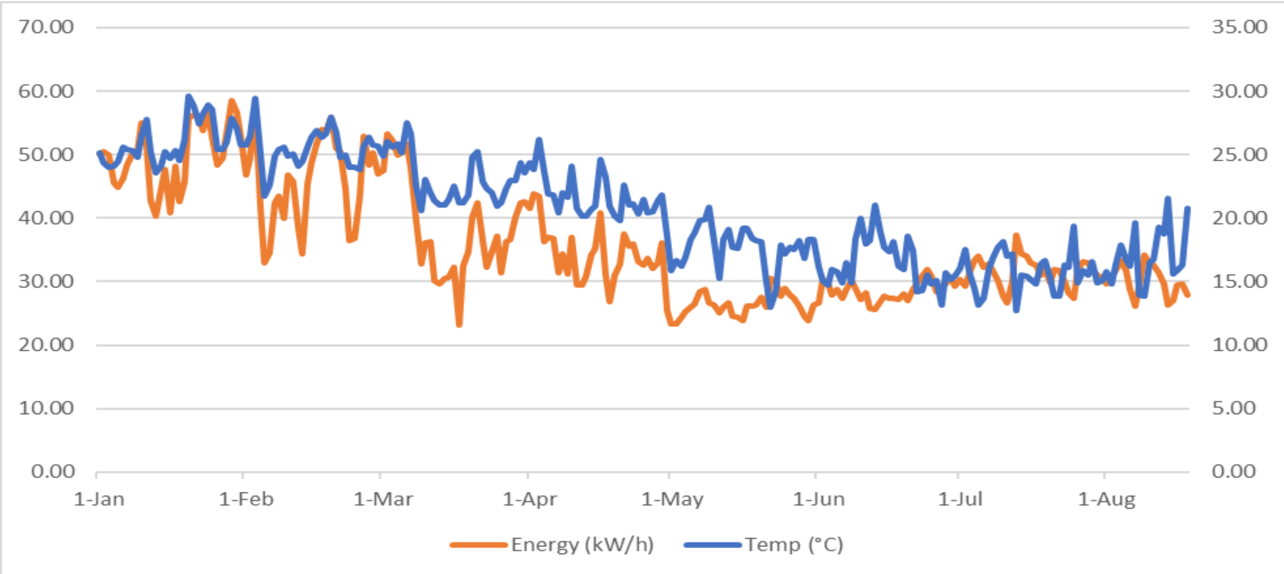

Figure 3-6 Daily temperature vs energy use for 2020

The impact of external temperature on energy use is supported by the significant correlation coefficient shown in Table 3-1 . The significant correlation across years 2015 to 2020 also shows that construction activities at Fernhill in 2019-2020 had a minor impact on the energy use.

Table 3-1 Correlation between temperature and energy use

	2020	2019	2018	2017	2016	2015
Pearson CC	0.827	0.779	0.82	0.779	0.887	0.852

There is no detailed sub-metering data available for the current (old) facility. Analysed sub-metering data from other Bolton Clarke RAC facilities are reported in the i-Hub's Healthcare Sector Baseline and KPI report. That analysis sought to understand what services contributed to energy use and power loads, the profile of those services, and who had control of those services.

3.2 Current Building Envelope Properties

The new RAC's building envelope performance was tested through comparing external to internal temperature for a 40 hour period in September 2020. Rooms 405, 406, and 408 were tested through temperature sensors placed in the middle of all rooms and on the balcony of room 405 (Figure 3-7). Rooms 405 and 408 are corner rooms facing north/east and north/west respectively, with glazing on both orientations. These rooms are more effected by solar heat gain and by heat conduction in general since the façade to floor ratio is larger than room 406.

Figure 3-7 Locations of sensors

The rooms are located on the top level, therefore they are more exposed to external conditions than the typical rooms on lower levels. Room 406 is facing north with one external wall and one window facing north (Figure 3-8). Data was collected every 30 minutes for around 40 hours, after the HVAC was turned off for the whole floor.

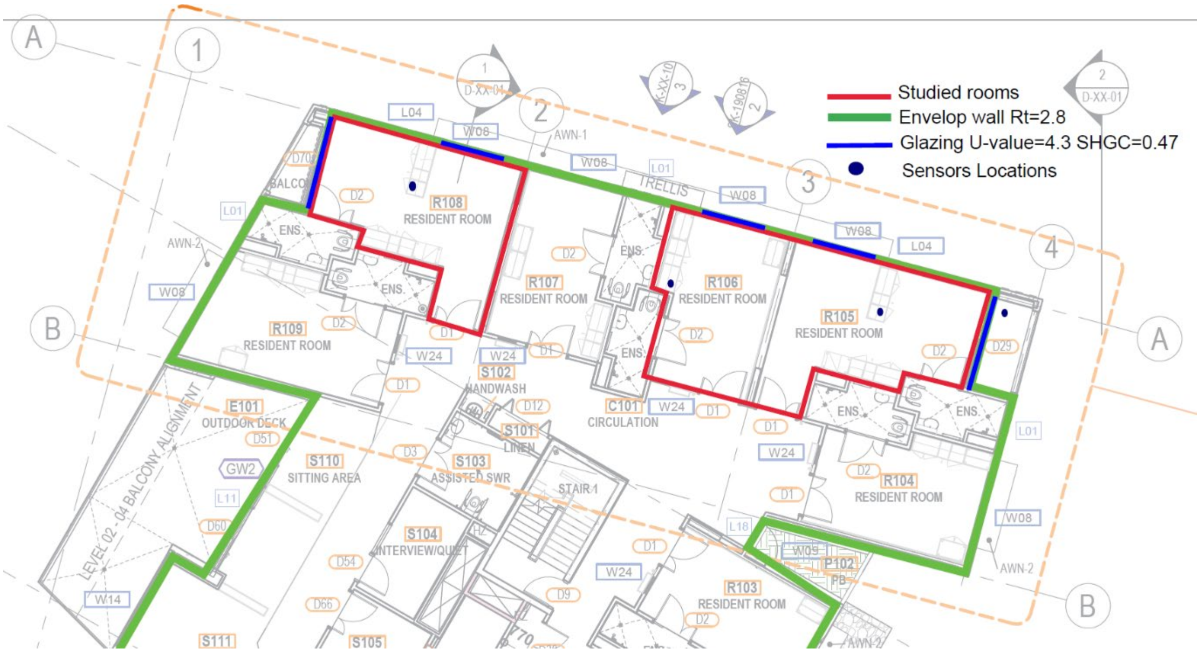

Figure 3-8 Studied Rooms

Figure 3-9 shows that the room 406 internal temperature is mostly stable which indicates good insulation. The envelope performs better in colder weather and during night time with a total difference between internal and external temperature reaching 10.9 degrees just before sunrise. The internal/external temperature difference drops to 1.8 at midday. Room 405 (facing east) shows a higher rise in internal temperature than room 406 at sunrise (between 7 to 10 am), which suggests that room 405 has more solar heat gain through the eastern facing glazing. In contrast to room 405, room 408 (facing west) shows higher internal temperature during sunset (between 4-6 pm). The graph demonstrates that room 408 is the worst performing room and most likely the room to consume most energy for cooling purposes due to its orientation. Additional tests will include heat flux sensors on the walls and glass to identify their thermal resistance. It should be noted that all external window shading for the building is via horizontal awnings, regardless of orientation.

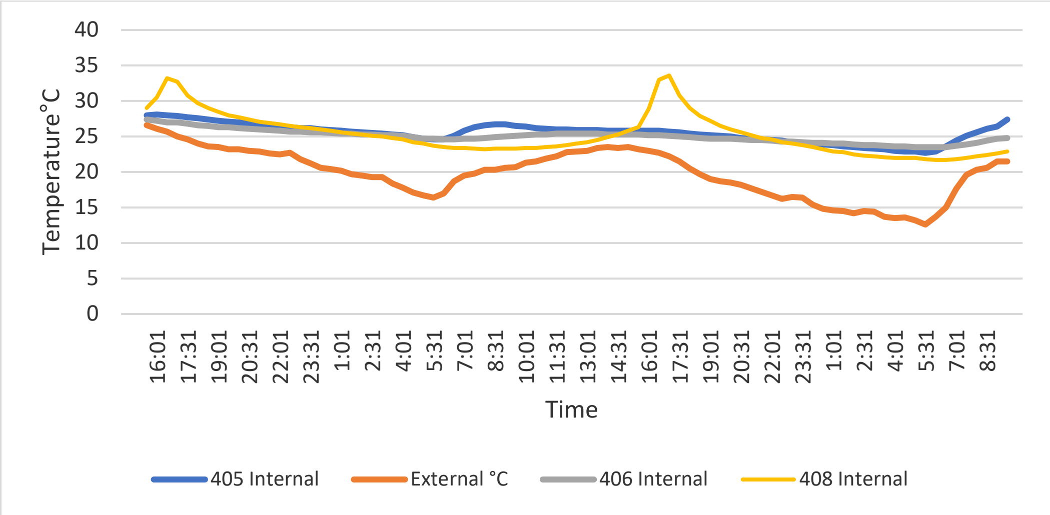

Figure 3-9 Comparing internal to external temperature

Figure 3-10 compares the 2 weeks external temperature data between rooms 405 (east) and 408 (west). The graph shows much higher external temperatures at room 408, reaching between 40 and 50 degrees, and occurring daily between 12:30 and 15:30 pm. This temperature difference could be attributed to the sun being directly on the dark surface which the sensor was fixed to. The actual external ambient temperature was not that high.

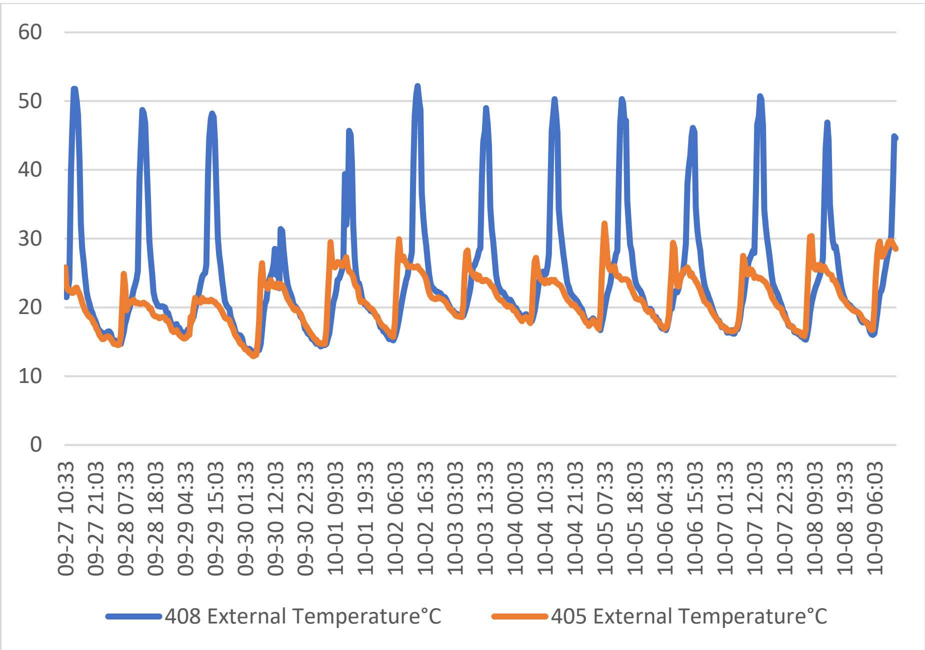

Figure 3-10 External temperature for rooms 405 and 408

Figure 3-11 shows Room 408 external vs internal temperature half hourly data for two weeks. The figure shows that there is about 10 degrees difference between the coldest internal and external temperature, and about 15 degrees between the hottest internal and external temperature. The graph shows that generally the building envelope helps protect the rooms from the extremes of external weather conditions. However, Figure 3-12 shows that daily internal temperature of room

408 is above a thermal comfort threshold of 25 degrees for 9 hours (between 2:30 to 11:30 pm), and above 29 degrees for 2.5 hours (between 4:00 to 6:30 pm) – without airconditioning. The room temperature however does not fall below the comfort threshold of 21 degrees, which suggests that overheating of the room is due to high solar heat gain through large glazing on the north and west facades.

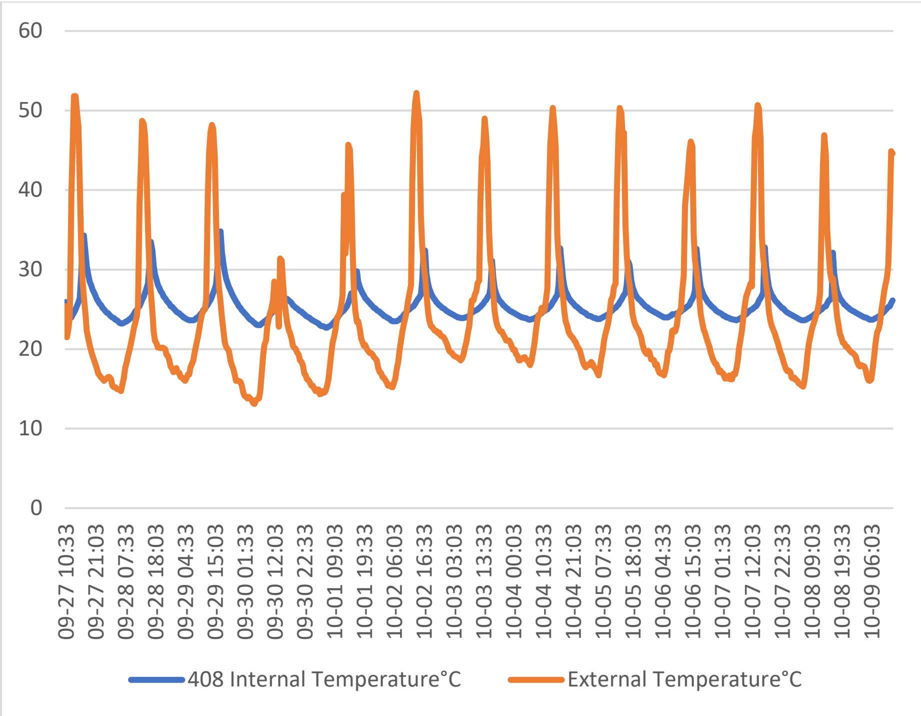

Figure 3-11 Room 308 internal vs external temperature

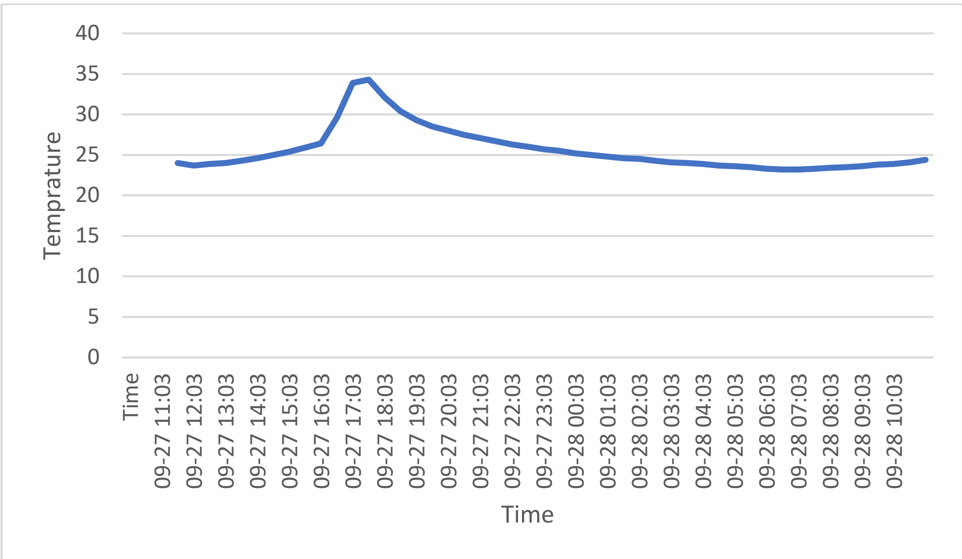

Figure 3-12 Room 408 daily internal temperature

3.3 Airtightness Testing

QUT engaged airtightness ATTMA accredited professionals to conduct air tightness testing of the newly constructed building prior to its occupation. The aim was to compare the actual air change rate of the building to the air leakage rate used at the design stage to determine the energy efficiency (JV3 for the National Construction Code; 1ACH.hr @ 50Pa). The actual air change rate can be used as a baseline to identify the effect of building sealing solutions on the overall permeability, energy efficiency and thermal comfort.

Originally it was planned for the whole building to be tested, however discussions with the builder showed that there is no feasible way of collectively sealing the on-floor exhaust system via damper isolation. Therefore, due to the large number (over 100 points) of exhausts/ header box systems, a decision was been made to conduct the test on one level only to be able to individually seal each exhaust fan (Figure 3-13) in a timely manner. This issue highlights the need for HVAC design that facilitates the possibility of airtightness testing, since it is now an accepted verification method in the National Construction Code Volume 1 2019. The test was conducted on level 4 (the top level) since it is likely the most prone to external air infiltration. The approximate envelope area for Level 4 is 6142 m^2.

Figure 3-13 Sealing of supply and exhaust vents

Methodology

In total of six Retrotec fan units (Figure 3-14) were used in this project to achieve the necessary pressure differential, controlled by Retrotec digital controller gauges. Level 4 was pressurised from three locations. All locations were on fire escape doors and evenly spread over the floor (Figure 3-15).

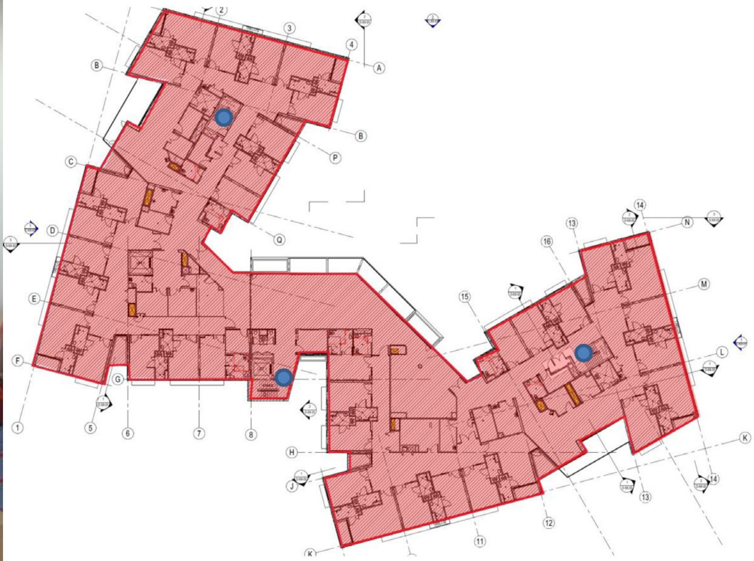

Figure 3-14 Blower door locations

Figure 3-15 Blower door setup

Each test space was prepared in general accordance with the AS/NZS ISO 9972:2015 Thermal performance of buildings - Determination of air permeability of buildings - Fan pressurization method and ATTMA Technical Standard L2: Measuring Air Permeability of Building Envelopes (Non-Dwellings) (October, 2010) and summarised as follows:

- Test area: Select test area based on the air barrier and the conditioned space.
- All doors between internal areas left open.
- All external doors and lift doors closed but not artificially sealed.
- Openings to ‘permanently open uncontrolled natural ventilation’ temporarily sealed.
- Motorised smoke dampers closed.
- Building ventilation system serving the testing area shutdown during test. System artificially sealed.

Results

Fan speed was carefully adjusted incrementally up until the desired test pressure differential of approximately 30 Pa was achieved. The results have been summarised in Table 3-2.

Table 3-2 Air leakage test results for level 4

Location	Air flow rate m3/h @ 50Pa	Air leakage rate m3/h/m2 @ 50Pa	Equivalent Leakage Area m2	Air Change Rate m3/h/m3 @50pa	Correlation coefficient (R2)	Air flow exponent (n)
Level 4	83547.83	13.60	4.1666	9.85	0.9857	0.7315
Target	-		-	1	≥ 0.9800	0.5 to 1.0

Visual investigation of leakage points was undertaken during the site visit to determine where deficiencies in the façade were located. Minor air leakage paths were observed, and were mostly located in the top and bottom of louver windows and between the sliding door panels (Figure 3-16).

Figure 3-16 Air leakage path in windows

Other leakage paths were observed in the ceiling space (Figure 3-17). However, due to access limitations the sizes/locations of the leakage areas above the ceiling were not identified. It was also unclear if the leakage is due to openings to the roof or due to an unsealed shaft/riser connecting to lower levels. Other minor leakage paths included the lift shaft and garbage chute. Cable risers between levels were investigated using the smoke gun and found to be well sealed (Figure 3-18). Additionally, smoke dampers were viewed as closed and drains were observed to contain water.

Figure 3-17 Openings in the ceiling space

Figure 3-18 Sealed floor penetrations in electrical cupboards

Test results show that the actual permeability of the building is higher than expected, and that it does not comply with the NCC Volume 1 2019 requirement of $5m^3/hr.m^2$. Sealing solutions/technologies could be tested as a part of the living lab to identify the reductions in the air leakage rate resulting from addressing some of the leakage paths outlined.

3.4 Potential technologies that could be in-situ tested

The purpose of the Fernhill Living Laboratory is to be able to test a range of products, equipment, software and building management approaches that have the potential to:

1. Improve the efficiency and performance of HVAC systems, such as water treatment, compression cycle efficiency, innovative heating-cooling mechanisms and filters;
2. Improve building envelope thermal performance (i.e. reduce external thermal loads), such as roof or wall coatings, smart glazing, envelope sealing solutions, or internal/external shading devices;
3. Reduce or control internal heat loads, such as smart lights and controls;
4. Integrate with building management systems to optimise building operation, such as demand management, load shifting, predictive maintenance, and continuous commissioning;
5. Provide onsite or neighbourhood renewable energy that can be utilised, stored and managed to meet site demands;
6. Enable demand response capability and other energy market trading mechanisms.

Such technologies could include (but are not limited to):

- Lighting with programmable colour temperatures to suit circadian rhythm
- Grid-synchronous generator
- Renewable energy (PV) – at a precinct level (e.g. utilising retirement village roofs)
- Electrochromic or thermochromic glazing
- Phase change materials (PCM) (e.g. in walls, ceiling, HVAC ducts)
- Grid synchronous generator
- Smart ceiling fans (to interact with natural ventilation, sensors and HVAC systems)
- Energy efficient / controllable louvre systems
- Energy efficient / controllable window dressings
- Energy/building management software solutions that enable continuous commissioning, building optimisation, or forecasting optimisation

3.5 Current and potential key performance indicators

Current aged care sector KPIs are typically based on kWh/bed as demonstrated in the previous section. To assist with energy management decisions, more detailed or purpose oriented KPIs may be needed. As indicated previously, the RAC precinct's energy use and power demand are seasonal and highly correlated to HVAC. Therefore, monthly KPIs or HVAC related energy KPIs can be helpful. Some possible KPIs that may be examined are presented in Table 3-3. Additional KPIs may be identified and tested over time, including KPIs that relate to health outcomes.

Table 3-3 Potential KPIs for Fernhill

Sector	Benefit	Possible KPI
Site benefits	Energy bill reduction	$ saved per month or per year
	Reduced energy intensity	kWh/bed
	Increased load shifting capability	kW or kWh
	Predictive control of load	kW
	Self-sufficiency / Resilience	% of self-sufficiency rate Or N-X contingency
Renewable energy	Energy bill saved from locally generated renewable	$ saved per month or per year
	Increased value proposition	% of energy from renewable
Environmental benefits	Avoided greenhouse gas emissions	tCO2-e $/ tCO2-e
	Avoided air pollution (PM10, NOx, and SO2)	Reduction in (PM10)/MWh Reduction in (PM10) ppm
	Improved IEQ in occupant rooms	T, RH, CO_2, VOC, LUX, Decibels
Network benefits	Peak 30 minute electricity demand	Peak kW/month (season, annual)
	Wholesale cost of peak 30 minute electricity demand	Wholesale $/KW at time of site peak demand
	Total self-consumption rate of local generation, e.g. renewable	%
	HVAC self-consumption rate of local generation, e.g. renewable	%
	Net Facility Load Factor	Peak demand to average demand ratio
	Demand response capacity	kW
Sector benefits	Energy cost reduced	$ per year
	Power Purchase Agreements - % of renewable energy	kWh of renewable energy purchased as a % of total PPA purchase
	Renewable energy fraction	kWh of renewable energy generated on precinct / neighbourhood

This manual outlines the processes that will be followed in operating the Living Laboratory at Fernhill Residential Aged Care. Technology providers are advised to read this manual carefully to understand whether this facility is a suitable avenue for testing of their technology.

4 MEASUREMENT AND VERIFICATION (M&V)

4.1 M&V techniques

All Measurement and Verification (M&V) techniques employed will be consistent with the International Performance Measurement and Verification Protocol (IPMVP), which outlines minimum requirements for calculating savings from energy efficiency improvement projects.

However, this Living Lab will differ from typical M&V in several key points:

- The measured output of the i-Hub project is the increase in the value of renewable generation, rather than simply increasing energy efficiency. This means that M&V will have increased complexity that includes considering energy use of HVAC-related equipment, energy generation of renewables and the potential energy demand management strategies to improve grid stability and reduce site costs.
- Some of the renewable energy and enabling technology benefits, for instance peak demand reduction and demand response (DR) capacity, may not be able to be metered or directly observed. Benefits could be calculated based on a comparison between the observed load, and a theoretical estimate of what the load would have been in the absence of the renewable energy or enabling technology.
- The specific technologies that will be (could be) tested in the Living Lab are unknown, and as such, the monitoring systems will need to be flexible, detailed and comprehensive.
- This project is a research-grade living laboratory, designed to delve deeper than the typical M&V project requirement to comply with the minimum standards of an accepted protocol in order to report the energy savings of an energy conservation measure.

As a result of these considerations, the M&V processes implemented in this Living Lab will go beyond those outlined in the IPMVP.

The key calculation principle to determine ‘savings’ from an intervention will be calculated as:

Savings = (Baseline Period Use or Demand – Reporting Period Use or Demand) ± Adjustments

where adjustments refer to calculations completed to account for differences in independent variables between the baseline and reporting periods.

This principle is illustrated in Figure 4-1, where ‘retrofit’ is equivalent to a technology intervention.

For this RAC, the major calculated adjustment is expected to be changes to external weather conditions.

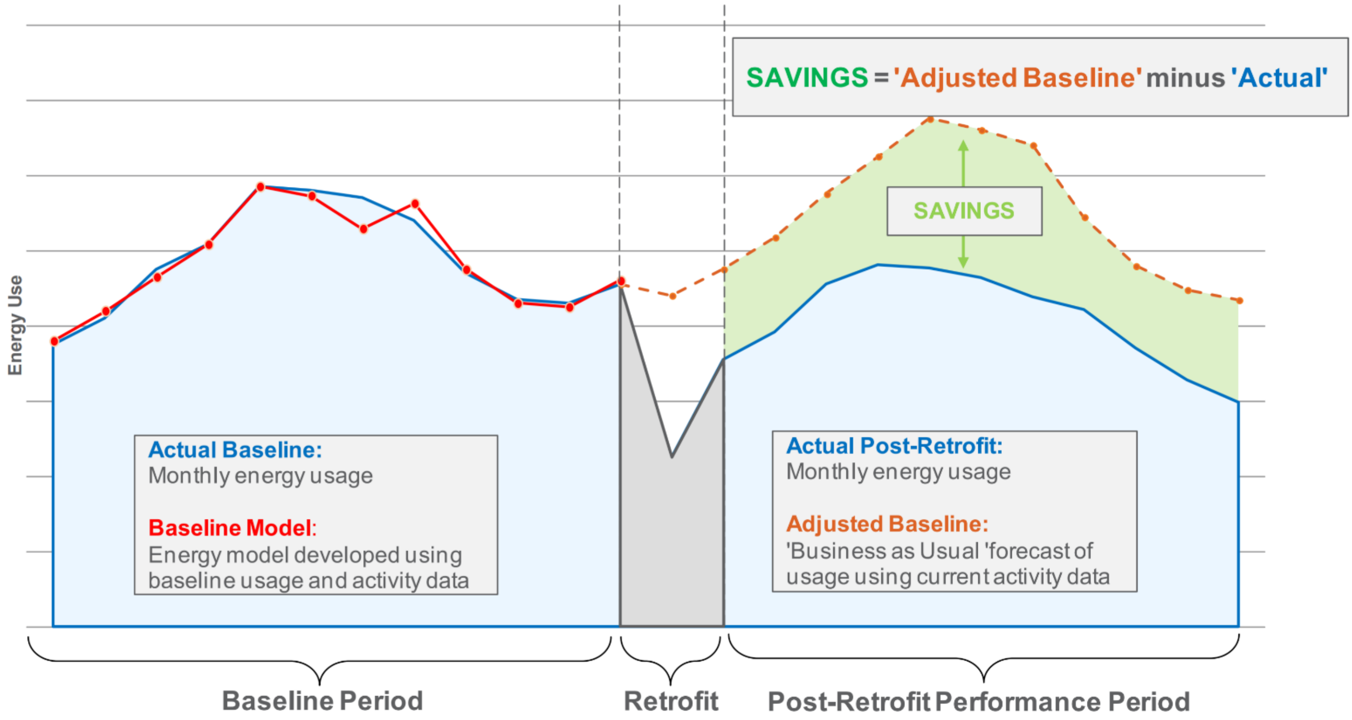

Figure 4-1 Savings calculation principle [2]

The IPMVP outlines four M&V options:

(i) Option A: Partially Measured Retrofit Isolation;
(ii) Option B: Retrofit Isolation;
(iii) Option C: Whole Facility (Building); and
(iv) Option D: Calibrated Simulation.

The option utilised for any technology test regime will depend on the technology and if, where and how it connects to Fernhill's energy system. Key conditions for selecting the most appropriate option include:

- whether the measurement boundary can be isolated for technology testing/intervention and all associated conditioned room(s);
- key parameters that may significantly influence the energy savings calculation (e.g. outdoor weather, occupancy patterns, and changes to key energy equipment);
- baseline data availability;
- building data to enable a simulation to be constructed and calibrated.

It is envisaged that technology testing / intervention will likely use Options B, C and D individually and/or in combination, as determined case by case. A summary of how these three options will be applied is shown in Table 4-1.

[2] https://www.environment.nsw.gov.au/resources/energyefficiencyindustry/120990bestpractice.pdf

Table 4-1 IPMVP Options B, C and D

Excerpt from IPMVP (2012): Overview of IPMVP Options	
IPMVP Option	**How Savings Are Calculated**
Option B. Retrofit Isolation: All Parameter Measurement Savings are determined by field measurement of the energy use of the ECM-affected system. Measurement frequency ranges from short-term to continuous, depending on the expected variations in the savings and the length of the reporting period.	Short-term or continuous measurements of baseline and reporting period energy, and/or engineering computations using measurements of proxies of energy use. Routine and nonroutine adjustments as required.
Option C. Whole Facility Savings are determined by measuring energy use at the whole facility or sub-facility level. Continuous measurements of the entire facility's energy use are taken throughout the reporting period.	Analysis of whole facility baseline and reporting period (utility) meter data. Routine adjustments as required, using techniques such as simple comparison or regression analysis. Non-routine adjustments as required.
D. Calibrated Simulation Savings are determined through simulation of the energy use of the whole facility, or of a sub-facility. Simulation routines are demonstrated to adequately model actual energy performance measured in the facility. This option usually requires considerable skill in calibrated simulation.	Energy use simulation, calibrated with hourly or monthly utility billing data. (Energy end use metering may be used to help refine input data.)

All methods require detailed and long-term monitoring of key parameters and independent variables. Options B and C use this data directly to create a regression model for normalisation. Option D uses the data to calibrate a building performance simulation model of the facility, which can then be simulated under consistent conditions for the baseline and reporting periods. Option D can use the baseline period data to calibrate and verify a building performance simulation model of the facility, which can then be used to simulate energy use under consistent conditions for both the pre-retrofit and post-retrofit configurations during the post-retrofit reporting period. The use of a validated and calibrated simulation will be better able to normalise for external conditions using representations of typical weather conditions than regression methods.

4.2 Defining the measurement boundary

The measurement boundaries for measurement and verification of HVAC-related technology upgrades are normally defined in reference to:

- A piece of HVAC equipment or energy system, including all the spaces it serves; or
- A separately zoned conditioned space, such as a room, or a group of rooms, which may contain multiple HVAC systems.

The measurement boundaries for the Fernhill will depend on the type of technology being tested, and may include, for example:

- A specific room or floor (e.g. for measuring the impact of a building element on reducing external heat gains, and hence the impact on HVAC load and energy use)
- A specific HVAC component (e.g. the chilled water system)
- A part of a building (e.g. the kitchen or laundry)
- A whole building
- The whole precinct (e.g. energy system optimisation through software connecting to the building management system)

It is not envisaged at this stage that the Fernhill will test technologies in clinically functional areas.

As one of the main goals of the i-Hub is to assess the change to the value of renewable energy, each technology assessment will include an evaluation of the impact of the technology on Fernhill's ability to increase the percentage of renewable energy that could be met by a roof-mounted PV system, and/or enable onsite precinct level or neighbourhood level renewable energy generation.

In general, all technology assessments will use either 'before and after' comparison or 'control and intervention' comparison in the case of resident rooms that are able to be effectively isolated.

4.3 Adjustments and constraints

IPMVP classifies adjustments as routine and non-routine adjustments. Routine adjustments are adjustments to the monitored data that were anticipated as part of the M&V plan, for instance adjusting for different weather conditions. Non-routine adjustments are unexpected events that require adjustments, for instance failure of a piece of equipment during the monitoring period.

Some constraints will be held constant between the reporting and baseline period. These constraints will be used to define the multi-variate regression model for adjustment of observed differences.

4.3.1 External conditions

In order to calculate weather corrected indices, the following external conditions will be monitored via the onsite weather station as described previously. Onsite weather data may be compared to the nearest Bureau of Meteorology site data, to determine any potential microclimate conditions.

4.3.2 Indoor environment quality

Internal conditions (e.g. temperature, relative humidity, and CO_2 levels) will be monitored as per Fernhill's building management system (relative to the area under test), and, for specific rooms, as described in Section 2.7. This is to ensure that comfort conditions are consistent between the baseline and reporting periods (or that the intervention has increased comfort conditions).

4.3.3 Energy plant performance

Energy plant performance (e.g. chilled water, air handling units, fan coil units) will be monitored as per Fernhill's building management system (relative to the area under test). This is to ensure that plant operation conditions are consistent between the baseline and reporting periods (other than those parameters that may be changed deliberately as part of the test regime being undertaken).

4.3.4 RAC operational changes

Major impacts on 'standard' Fernhill precinct operation will be taken into consideration (e.g. if there is a major disease or illness that increases or decreases typical occupant numbers or staff activities; or if there is a major change in retail tenancy).

5 MONITORING AND METERING REQUIREMENTS

The monitoring and metering at Fernhill RAC have been explained previously in Section 2. The need for additional meters will be considered on a case-by-case basis to enable appropriate measurement and verification of technologies being tested. Either QUT or an external independent contractor will be engaged to provide / manage any such monitoring and metering as is required, and as approved by Bolton Clarke. Any additional devices added need to meet the following criteria:

- Be suited for the M&V purpose
- Be approved by Fernhill (and their installation / use managed by Fernhill)
- Meet relevant Australian Standards (or equivalent)
- Be calibrated
- Enable remote access to the data, or ongoing data download
- Have fault alarms

6 DATA ANALYSIS METHODOLOGIES

Depending on the purpose of technologies under test, three types of data analysis methodologies will be used: quantitative, qualitative, or simulation (or a mix of all three).

6.1 Quantitative analysis

Quantitative analysis will be used to analyse the impact of innovative technologies to improve HVAC efficiency, reduce peak demand, control energy loads, enhance energy productivity and add value to renewable energy options. Methods may include regression analysis, ANOVA analysis, distribution and modelling, simulation and forecasting, unsupervised machine learning etc. Quantitative analysis will also include financial analysis incorporating, for example, cost benefit analysis, cash flow, internal rate of return, etc.

6.2 Qualitative analysis

Qualitative analysis will be used to analyse the impact of innovative technologies on building users and building managers. Instruments such as surveys, questionnaires, interviews and focus groups can be used to obtain qualitative data. Such data could include, but is not limited to:

- The impact (positive, negative, none) on occupant comfort (thermal, visual, acoustic, air quality)
- The impact on clinical and administration staff (if the equipment relates to their work or working environment)
- The impact on facilities management (e.g. operational complexity, maintenance regime, staff training)
- The impact on asset management (e.g. total cost of ownership)

6.3 Modelling / simulation

Building simulation is Option 4 under the IPMVP process as discussed previously. A virtual model of the RAC, as operated, is expected to be developed from the REVIT model used at the design stage. Building simulation can then be used to extrapolate findings to the broader aged care sector (e.g. simulating the model in different climate zones). This will assist in calculating potential sector wide benefits of the tested technologies.

A model of the HVAC system can be used to test 'what if' scenarios in terms of changes to plant operation. The use of modelling provides certainty to building operators of the likely impacts of changes to building operations, and dramatically reduces the risks associated with making changes to facilities management.

7 POST OCCUPANCY EVALUATION PROTOCOLS

Post Occupancy Evaluations (POE) are designed to obtain feedback on the operational performance of a building, and to assess the extent to which the building satisfies the needs of its occupants. POE use interviews or questionnaires with the building occupants to explore perceptions of thermal comfort, ideally with concurrent 'right here, right now' IEQ physical parameter measurement. POE are designed to complement the physical measurement of thermal environmental parameters and provide deeper insights into occupant and context specific thermal comfort issues.

POE are a well-established building assessment tool, and there are numerous approaches that can be employed. For example, Brambilla and Capolongo (2019)[3] have reviewed POE tools for

[3] Brambilla, A, Capolongo, S (2019). Health and Sustainable Hospital Evaluation – A Review of POE tools for hospital assessment in an evidence-based design framework. *Buildings*, 9(76). DOI:10.3390/buildings9040076

aged care environments, and the US Federal Facilities Council (2001)[4] explored the evolution of POE and state-of-the-art POE practices for building improvement.

There are several well-established standardised methods for conducting POE, which were originally designed for use in office buildings. These methods use standardised questionaries, and the results for a facility can be compared against the performance of other similar facilities in the database. A concise summary of the most relevant and frequently used standardised approaches for a POE are shown in Table 7-1.

For the purpose of the current REETSEF, it is acceptable to employ any of the standardised POE methods outlined in Table 7-1 or develop alternative tailored surveys that cover areas relevant to the impacts of the technology being tested on occupants. Bespoke POE designed for aged care facilities are also acceptable, however the survey instruments must be reviewed and approved by both an approved HREC committee, and the i-Hub education steering committee.

Table 7-1 Summary of standard POE tools

Tool	Developed and main usage	Benchmarks	Method	More information
Building Use Studies (BUS)	UK	UK, NZ, Canada, Australia and International non-domestic; UK housing; UK schools benchmark	5 – 15 min questionnaires	busmethodology.org.uk/
CBE Occupant Survey Toolkit	USA	Office buildings; Laboratories; K-12 schools; Higher education; Residence halls;	10 min web-based survey	cbe.berkeley.edu/resources/occupant-survey/
BOSSA	AUS	Office Buildings;	10 min survey	www.bossasystem.com/

[4] Federal Facilities Council (2001). *Learning from our buildings: a State-of-the-Practice Summary of Post-Occupancy Evaluation.* Federal Facilities Council Technical Report No. 145. National Academy Press, Washington DC.

8 CONTRACTUAL ARRANGEMENTS AND ETHICS PROTOCOLS

8.1 Contractual arrangement

Queensland University of Technology (QUT) has an agreement with Bolton Clarke regarding how Fernhill Living laboratory operates.

Prior to site work relating to any technology to be tested, a written agreement needs to be signed between QUT and the approved technology supplier. This agreement will stipulate the roles and responsibilities of all parties with regard to testing technologies within the Fernhill Living Lab. The agreement will include, as a schedule, the approved product testing plan that is developed by QUT in conjunction with Fernhill Facilities Management and the technology provider.

8.2 Ethics protocols

In general, this project focuses on technical studies of innovative technologies in improving HVAC efficiency, reducing energy use/demand and enabling renewable energy. However, one of the purposes of Living Laboratories is to deliberately include ‘users’ in the evaluation of technologies. Different categories of ‘users’ and how they could be involved, was presented in Section 7.2 (qualitative analysis). All such activities will require approval by both QUT’s Research Ethics Committee and Bolton Clarke’s Research Ethics Committee. It is the responsibility of QUT’s Project Manager and Bolton Clarke’s lead participant to ensure that the relevant processes are followed and approvals received before collecting data from any building occupant or user (other than those directly involved in the Living Lab).

9 INTELLECTUAL PROPERTY (IP) PROTOCOLS

9.1 Intellectual property

Bolton Clarke and QUT jointly own this Fernhill Living Lab Prospectus and Manual, with rights assigned to AIRAH/i-Hub to utilise the document for the purposes of operating the Living Lab and all associated activities. No commercialisation of this Prospectus and Manual is permitted.

All background IP (i.e. intellectual property that exists prior to any product testing) will remain vested with the relevant party. Pre-existing material (such as that outlined in Section 10.3.1) provided by a technology provider to QUT and Fernhill will only be used for the purposes of product testing.

The Technical Report (for a specific technology) will include the technology test plan (how the test was conducted) and the results. It will be owned by QUT and published under Creative Commons (with attribution). **It is a requirement of i-HUB funding that all test results be made public** (without the disclosure of pre-existing commercial-in-confidence material).

The test report will be published, as a minimum, on the i-HUB website.

Test results may also be communicated by QUT in other ways, such as through academic publications, industry seminars, sector wide publications etc.

Test results can also be used by the technology provider for product development and commercialisation purposes. In all instances, the full Technical Report should be referenced, and test results should be fairly and accurately communicated by ensuring there is appropriate acknowledgement of the context, boundary conditions, test parameters and limitations of the test results.

9.2 Confidentiality

All parties are bound by confidentiality requirements. The provision of commercial-in-confidence information by technology providers for the purposes of product testing does not permit QUT or Bolton Clarke to disclose that information to any other persons or for any other purposes. Conversely, technology providers are not to disclose any information about QUT or Bolton Clarke / Fernhill that they may gain access to during the product testing processes. This includes patient or employee personal information, clinical data, and building and operations data.

10 TECHNOLOGY SELECTION PROCESS

10.1 Application process

10.1.1 Expression of interest / selection criteria

Potential technology providers are to, in the first instance, contact the i-Hub (www.ihub.org.au) or the Fernhill Living Lab project manager. The technology provider will be encouraged to complete an Expression of Interest (EOI) form, in which they will communicate how they envisage their technology can meet the overall objectives of the i-Hub as well as be applicable for this Living Lab.

To be eligible for testing with i-Hub Fernhill Living Lab, the potential technology suppliers need to:

- Be an Australian registered company
- Demonstrate that the application of the innovative technology may meet one or more of the i-Hub project goals:
    - control and optimisation strategies that can provide the essential energy services cost effectively;
    - renewable energy supply options that reduce exposure to rising commodity prices;
    - demand response capability to reduce exposure to peak demand pricing and extreme weather events.

10.1.2 Initial meetings

QUT will organise an initial meeting with the technology provider to discuss the technology and its current stage of development. If considered potentially suitable for the Fernhill, a follow up meeting will be conducted between the technology provider, QUT and Bolton Clarke representatives. This will include onsite visits so all parties are fully aware of the Living Lab conditions and limitations.

10.1.3 Project planning

On verbal agreement by Bolton Clarke to potentially test the proposed technology, QUT will facilitate further meetings between all parties to plan the technology testing regime and scope. Technology providers will be expected to:

- Sign a collaborative agreement with QUT relating to the test regime (refer to Section 8.1);
- Satisfy the business considerations, engineering, risk management and legal requirements (outlined in the following sections); and
- Be responsible for the installation, commissioning, maintenance and decommissioning of their equipment, for the duration of the test regime, and in accordance with any and all requirements of QUT and Bolton Clarke.

10.2 Business considerations

This section outlines the core business aspects that technology providers need to comply with, in order to be considered for this Living Lab test regime.

10.2.1 Business registration and taxation status

In addition to provide register company name, address and contact details, companies will be asked to provide details of their business, such as Australian Business Number (ABN), Australian Company Number (ACN) and Tax File Number (TFN).

10.2.2 Insurances

Companies will be asked to provide details of relevant insurances, such as

- Public Liability (PL)
- Professional Indemnity (PI)
- Product warranties

10.2.3 Living Lab bond

In some instances, technology providers may be required to pay a Living Lab bond – an amount that covers the potential cost of removal of the technology at the end of the testing period. The amount of this bond is to reflect the level of risk and cost associated with removal of the technology at the end of the test period, should the technology provider become insolvent or otherwise unable to decommission and remove the technology.

10.3 Engineering and risk management considerations

As part of the Living Lab's due diligence, technology providers will need to meet a range of engineering, risk management and legal requirements as discussed below. This list is indicative, not exhaustive. Additional requirements may need to apply to specific technologies: these will be raised with companies in the discussion phase.

10.3.1 Engineering requirements

The technology proposed to be tested must meet Australian legislation and standards when there are relevant Australian legislation or standards. In case there is no relevant Australian legislation or standard for the technology, relevant European/US standards (e.g. BS, EU, ISO, IEC, ASHRAE, ASME, IEEE) would need to be referred to.

Technology providers will be required to submit the following information relative to the specific technology to be tested:

- certified copies of any previous test results;
- all technical specifications and performance information (including, for example, Material Safety Data Sheets);

- all instructions (including installation, commissioning and operation information);

Such information will be treated in confidence by QUT and Bolton Clarke and will only be used for the purposes of determining an appropriate test plan.

10.3.2 On-site work requirements

All onsite technology test work needs to comply with QUT, Fernhill and Bolton Clarke's workplace HSE requirements, as well as site specific requirements, such as site induction, building or area specific induction, work method etc.

A section of the written agreement between QUT and technology providers will include specific requirements from Bolton Clarke, relative to the technology being tested.

10.3.3 Risk management

The Fernhill Living Lab has a comprehensive Risk Management Plan (RMP) and Health, Safety and Environment (HSE) Plan. Technology providers and associated contractors will be required to work collaboratively with QUT and Fernhill / Bolton Clarke staff to assess possible risks associated with the proposed technology, and to develop appropriate risk management strategies. These risks are to be added to the Fernhill Living Lab RMP and HSE Plan and signed off by QUT and Bolton Clarke.

All work done onsite will require the approval of Fernhill Facilities Management. This will be given through the signing of an agreed Work Method Plan.

11 TECHNOLOGY TEST REPORTS AND DISSEMINATION

The test report will be in the form of a Test Plan and Technology Evaluation Report (TER). The first part of the report – the Test Plan- will include, as relevant, the following sections:

- Introduction (problem statement, technology background, objectives)
- Test item (description of test item, approach, pass/fail criteria, expected results)
- Risk Management considerations, management
- Test environment and infrastructure
- Roles and responsibilities
- Methodology
- M&V plan
- Test plan (milestones, schedule)

The Results section will include, as relevant, the following sections:

- Test results (quantitative, qualitative, cost effectiveness)
- Overall technology assessment (extrapolation to other buildings / sector etc)
- Barriers and enablers to adoption
- Recommendations

The report will be disseminated according to ARENA's Knowledge Sharing requirements for iHUB projects. This may include, but is not limited to:

- Publication of the report on the iHUB website
- Utilisation of results in other publications by QUT (e.g. academic articles)
- Dissemination through the Renewable Energy Knowledge Sharing Task-Group for Healthcare
- Incorporation into other Living Lab outputs, such as the "Renewable Energy and Enabling Technology and Services Roadmap for Healthcare"
- Integration of the results into other iHUB outputs, such as AIRAH webinars, industry publications, conferences, seminars etc.
- Publications by the technology provider, as long as reference to the full report is provided, and the context of the test conditions and limitations are clear and unambiguous.