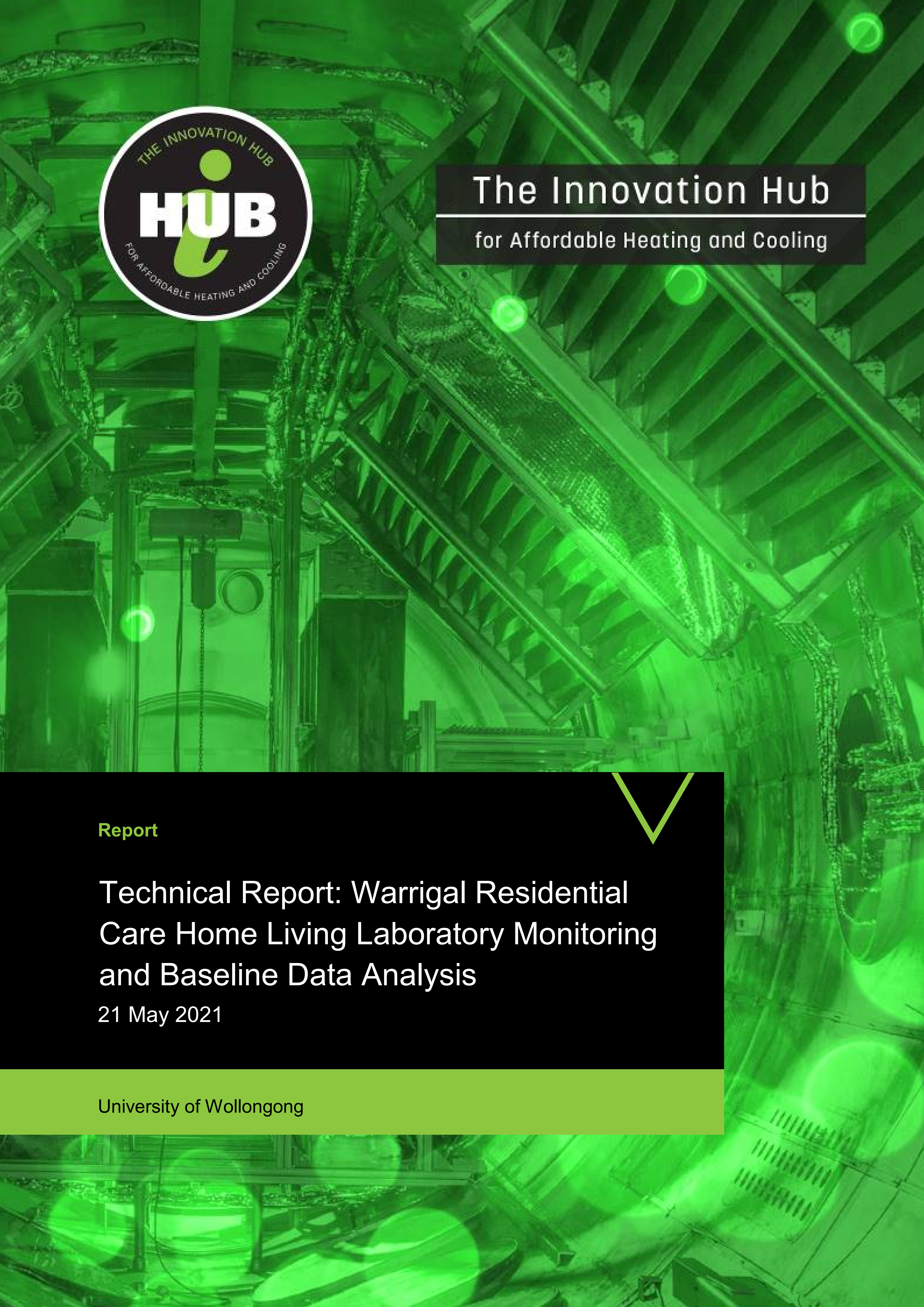

The Innovation Hub
for Affordable Heating and Cooling

Report

Technical Report: Warrigal Residential Care Home Living Laboratory Monitoring and Baseline Data Analysis

21 May 2021

University of Wollongong

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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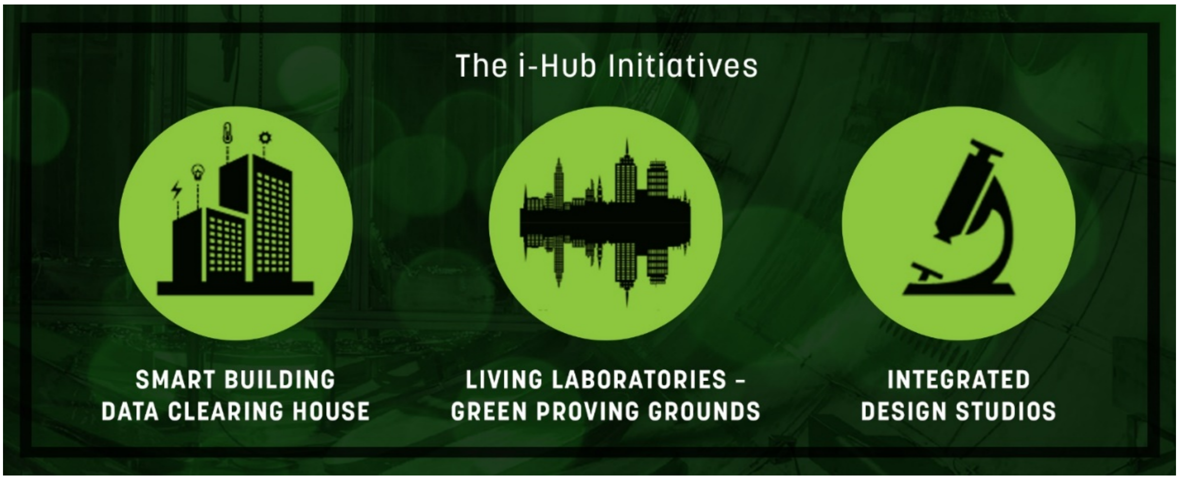

[Technical Report: Warrigal Residential Care Home Living Laboratory Monitoring and Baseline Data Analysis]

This Technical Report: Warrigal Residential Care Home Living Laboratory Monitoring and Baseline Data Analysis details the as-installed monitoring and evaluation capabilities implemented in the Warrigal Residential Care Home to meet the requirements of the i-Hub Healthcare Renewable Energy and Enabling Technology Evaluation Framework, as well as an initial baseline data analysis, to demonstrate available data sources and analysis techniques.

University of Wollongong (UOW)

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1.0	23/10/2020	Released for comment by AIRAH and ARENA	D Daly	C McDowell
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Please note, this a living document that will be iteratively updated during the establishment and operation of the foundation living laboratories. The above table only tracks major published updates. Please download the latest version from Note: Insert Public Link After Major Feedback from AIRAH and ARENA Implemented.

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1 Introduction

1.1 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.

1.2 Warrigal Residential Care Home Living Laboratory

The Warrigal Living Laboratory is situated in the innovative coastal community village of Warrigal Shell Cove, in the Illawarra region and was opened in 2017. This facility integrates aged care and independent living units into the local community and offers a range of villas and apartments suiting relaxed low maintenance living. At the centre of Shell Cove is The Quay, featuring beautifully designed shared spaces and a range of hospitality and wellbeing amenities. Warrigal Shell Cove's residential care home, situated in The Quay, provides a range of high quality residential care, including 126 beds and 6 serviced apartments. This living laboratory focusses on Level 2 of the residential care home which consists of 64 beds and a number of shared spaces. Renewable generation includes a large array of solar panels. Heat recovery VRF (variable refrigerant flow) heat pump systems serve the buildings heating and cooling needs.

This living laboratory provides research-quality measurement and verification systems within the this existing aged care ecosystem, where we will test and offer independent evaluations of the benefits of emerging HVAC&R, renewable energy and enabling technologies in context of daily life. The technology upgrades trialled in this living laboratory will be selected from promising electric heating and cooling strategies that increase the energy flexibility of this Warrigal facility and deliver increased value for renewable energy, at the site and grid level.

Figure 1-1: Aerial location photograph of the Warrigal Shell Cove Residential Care Home living laboratory.

1.3 About this report

This report provides an initial baseline analysis of the Warrigal Shell Cove Residential Care Home living laboratory. The purpose is to evaluate the data collected to this point against the KPIs defined in the Renewable Energy and Enabling Technology and Services Evaluation Framework (REETSEF). Due to the short time period of the living lab being operational not all of the KPIs were able to be meaningfully evaluated for this initial analysis. This report will be updated with a final baseline analysis following the recording of summer data.

This report should be read in conjunction with:

- Living lab manual: which details the specifics of the Warrigal Living Laboratory including the living lab boundaries, equipment within the facilities, monitoring equipment, and building schematics. The latest version can be downloaded via https://cloudstor.aarnet.edu.au/plus/s/f4xCnqxgfi6lyXJ/download.

- REETSEF: which defines the KPIs and methods of evaluation to be used to assess the impact of a technology upgrade on the value of renewable energy to an educational facility under the i-Hub living laboratory activity stream. The latest version can be downloaded via https://cloudstor.aarnet.edu.au/plus/s/J5TE6le6NnK5uIR/download.

2 Warrigal Living Laboratory description: 'THE QUAY', SHELL COVE

2.1 Monitoring Details

The schematics and lists, as presented in the figures in this section comprise the primary documentation for the real time monitoring system, with some supplementary explanatory notes included below.

2.1.1 Measurement Boundaries

The measurement boundary of the living laboratory at Warrigal Shell Cove encompasses the residential care home, The Quay, at a utility meter level. More detailed monitoring of energy at an equipment level and of indoor environment quality (IEQ) at a room level is focussed upon level 2 of The Quay, with a group of ten rooms served by a single condenser unit in the north east corner having a further level of IEQ monitoring installed. The community village independent living villas and apartments on the same site are not included in the living laboratory, as outlined in Figure 2-1.

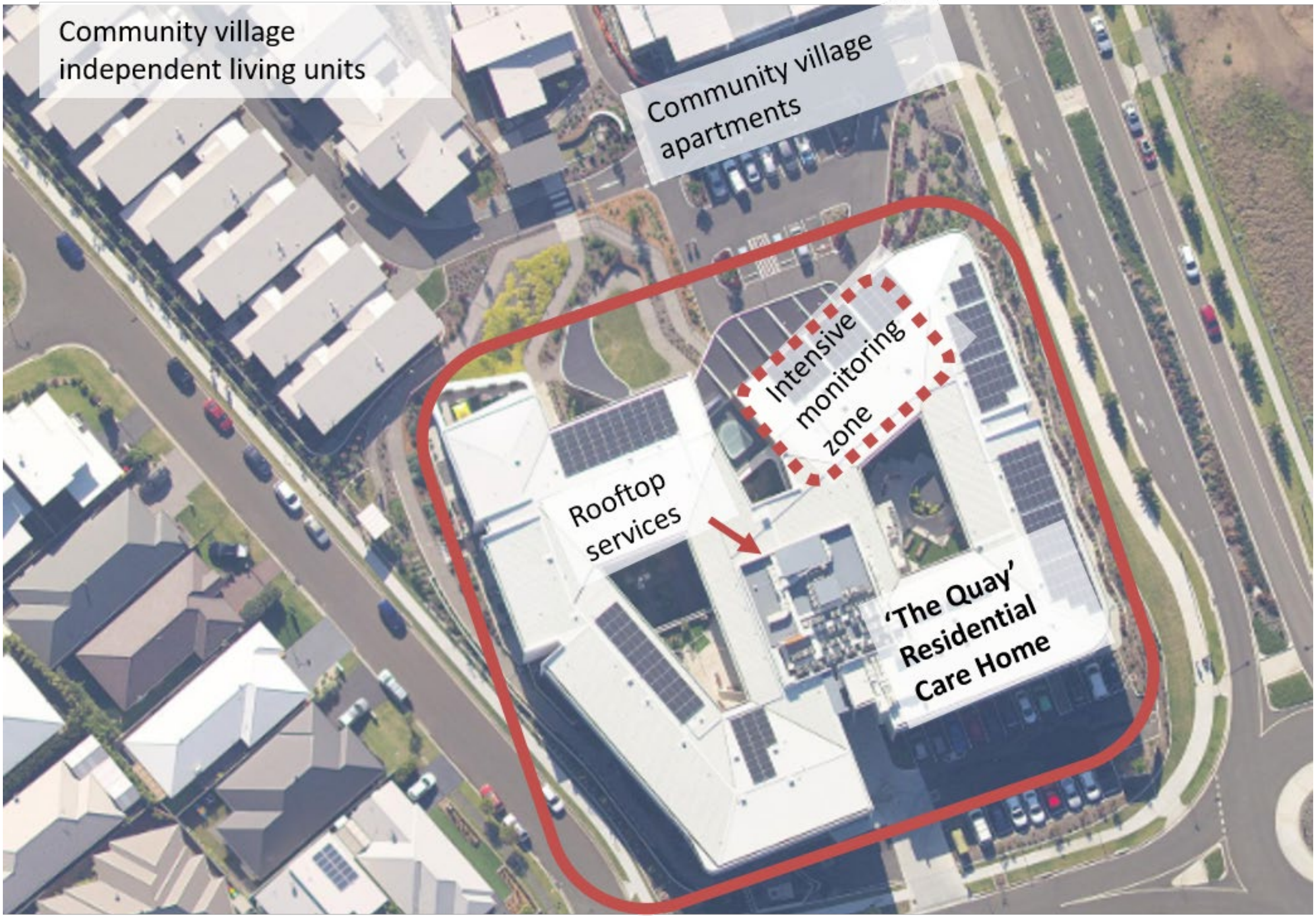


Figure 2-1: Aerial view of the site with 'The Quay' residential care home highlighted with the dotted line and the living laboratory detailed monitoring area outlined in red. Notice also the rooftop services area and the enclosed courtyard areas.

This facility has some unique features that provide opportunities and challenges to defining the measurement boundaries. Firstly, the technologies to evaluate are unknown and may vary in scope ranging from the whole building, such as BMS control strategies or energy storage, down to the level of a single condenser unit (with its group of fan coil units), or even a single room level technology with different controls or delivery method. Secondly, the advanced, all-electric VRF and AE-200 HVAC technology provides opportunities to increase the value of the large PV generation. The HVAC system also provides convenient sub-monitoring opportunities of energy consumption and room temperatures for comparable sections of the building HVAC.

This living laboratory may be usefully considered as offering a range of three levels of monitoring, as below.

2.1.1.1 Site/building monitoring

All three levels of 'The Quay' residential care home building are taken as the 'site' for this living laboratory. Site monitoring is an essential requirement in order to evaluate the impact of HVAC technology upgrades upon the renewable generation at the site level. Site monitoring may also be useful in this living laboratory to directly evaluate any facility-wide technologies, such as a BMS upgrade or centralised thermal storage.

The existing site electricity metering and HVAC temperature feedback data are sufficient to conduct an M&V Option C evaluation of all three floors of The Quay.

Site energy utility metering is detailed in Section 2.1.2 below.

Total site HVAC energy consumption is monitored at the mechanical services switchboards MSSB-G.1 and MSSB-R.1 to enable a comparison of the total HVAC energy consumption with total facility consumption and total facility renewal generation. External weather measurement for the local site is detailed in 2.1.3.5.

2.1.1.2 Building Level 2 detailed monitoring area

Each HVAC electrical load that serves any conditioned space on Level 2 is individually monitored at a circuit level thus individual components or the complete HVAC subsystem within this area may be upgraded and evaluated within this living laboratory. Each condenser unit 3-phase supply is individually monitored. Each group of fan coils units, served by a particular condenser unit, is fed from a common single phase circuit, resulting in the total fan coil unit group energy being aggregated. To disaggregate this, fan coil unit run times may be extracted from the HVAC controller.

These individual loads may then be aggregated to an individual FCU/room, condenser zone, and whole of Level 2 as required.

Indoor temperature is monitored for each conditioned space within this living laboratory. This is a minimum requirement to ensure that indoor temperature service quality remains comparable between the reporting and baseline period, and that any differences in service quality may be compensated for in the model.

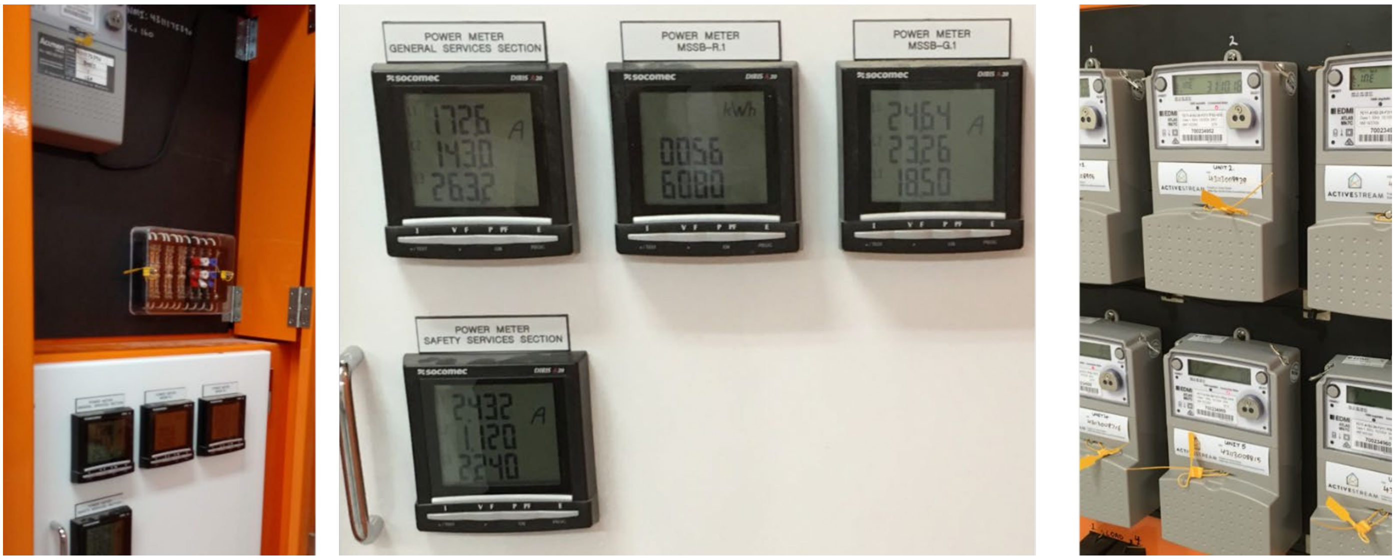
This requirement is met by capturing the existing HVAC controller room temperature data as well as through project-specific IEQ sensors (see Section 2.1.3.3) installed in a sample of Level 2 rooms. Room temperature set point (cooling and heating) and feedback are available from the Mitsubishi Electric AE-200 controller for each conditioned space on Level 2 and some Ground Level and Level 1 spaces. The project specific IEQ monitoring includes Nube iO Droplets, Elsys ERS CO_2 sensors, and Elsys EMS sensors in a sample of rooms across Level 2 as described in Section 2.1.3.3. Monitoring equipment layouts and lists are in Section 2.1.5.

2.1.1.3 Detailed IEQ monitoring zone -- Level 2 northeast corner

Ten rooms in the northeast corner of Level 2 (rooms 2-33 to 2-42) are set up to provide a more detailed study area with an Elsys ERS CO_2 (temperature, humidity, CO_2) sensor and an Elsys EMS (window opening and temperature/humidity) sensor in every room. These rooms cover both north and south-facing aspects and may provide an opportunity for detailed case studies and comparisons of occupant behaviours. These rooms constitute the whole HVAC zone served by condenser unit CU-17.

2.1.2 Site energy utility metering

The site has a smart net electricity meter located in the main switchboard on the ground floor (Figure 2-2 a top left and as per the single line diagram of Figure 2-4). This meters net electricity consumption for the total of all three levels of the residential care building. Sub-mains metering is also present as indicated in Figure 2-2 b. Each of the six serviced apartments on the ground floor are independently smart metered (Figure 2-2 c).



(a) (b) (c)

Figure 2-2: Electricity metering in the main switch room on ground level: (a) the site utility net meter (top left) with four non-utility sub-meters below; (b) detail of the sub-meter panel, with general services section, MSSB-R.1, MSSB-G.1, and safety service section in order from top left to right; (c) six smart utility meters for the serviced apartments on ground level.

The rooftop solar PV system feeds directly into the roof-level mechanical services switchboard with total generation separately monitored at this point. Gross metering of site load is not directly possibly due to this configuration.

Gas is metered for this whole building.

2.1.3 Monitoring equipment details

The monitoring system design provides for remote automated access for regular (typically daily) updates of data from each data source for the purposes of fault checking, data continuity and progressive data analysis.

An indicative sensor network diagram with physical device photos is presented in Figure 2-5, while Figure 2-8 provides specifications for each device with reference to the symbol legend.

Each monitored parameter for this site is listed in Table 2-2. This list is generated from the HVAC equipment asset register, as well as the REETSEF parameter list.

Further details of each type of monitoring device are included below.

2.1.3.1 Electricity consumption

The Wattwatchers Auditor-6M (see Figure 2-5) are a metering-grade electrical energy monitoring device measuring real power, power factor, and logging at 5-minute intervals. Each device has six channels, which may be configured variously to monitor:

- 3 phase gross consumption + 3 phase gross PV generation
- 3 phase load + 3 off single phase loads in a switchboard
- 6 off single phase loads

These A6M devices have 3G SIM cards installed with a monthly subscription fee for this service per device.

2.1.3.2 Gas consumption

Gas is only used for hot water and cooking and is not used for HVAC in this facility, so was not monitored in any further detail than the existing utility gas meter.

2.1.3.3 LoRa IEQ sensors

A combination of Nube IO and Elsys (IoT) sensors (see Figure 2-5) are installed in most conditioned spaces on Level 2 of the living laboratory. They communicate over the LoRa wireless IoT network designed for very low power, long battery life with reasonably long range wireless transmission.

Nube iO Droplet DL-TH devices are installed in 25 of the conditioned spaces on Level 2. These devices monitor temperature and relative humidity.

Elsys ERS CO_2 sensors are installed in 28 of the conditioned spaces on Level 2. These devices monitor temperature, relative humidity, carbon dioxide concentration, occupancy and light levels.

Elsys EMS sensors are installed on windows of 15 rooms in Level 2. These devices employ a magnetic reed switch to monitor window open/closed status and window opening counts during each sample period. Temperature, relative humidity and 3-axis accelerometer sensors are also included.

These room temperature and humidity sensors are installed at a height of nominally 1.1m above floor level in a location that does not receive direct sunlight at any time of the day in any season, not immediately adjacent to any glazing or heating/cooling outlets, and not on an external wall. For this site these sensors were all mounted directly underneath the HVAC wall controllers for that room. Each installed temperature and humidity sensor was calibrated in the laboratory against certified sensors.

The EMS sensors are mounted directly on the fixed window frame with the magnet mounted onto the operable window. As such, the temperature and humidity readings of these sensors will be affected by outside air when the window is opened and by solar radiant heat and external wall heat flux while the window is closed.

2.1.3.4 BMS data

The Mitsubishi wall controllers and AE-200 central HVAC controllers serve the facility with control and monitoring of room temperature feedback measurement and setpoint (heating and cooling) control in each conditioned space. Condenser and fan coil unit run time data is also available from the HVAC control database. These temperature sensors are incorporated into the wall controllers of each room near the main entrance to each bedroom. The calibrated LoRa IEQ Droplet and ERS CO_2 sensors may provide and indicative calibration offset.

2.1.3.5 Weather station

A Davis Instruments wireless integrated sensor suite plus with fan-aspirated radiation shield (model number 6328AU) weather station and data logger are installed on site (see Figure 2-6) to collect localised weather data for the living laboratory. The features include a rain collector, temperature and humidity sensors, anemometer, solar radiation sensor, UV sensor, sensor mounting shelf, and solar panel. For improved accuracy, temperature and humidity sensors are housed inside a solar-powered, 24-hour fan-aspirated radiation shield. The shield protects against solar radiation and other sources of radiated and reflected heat.

A WeatherLink Live USB (model number 6100USB) publishes the weather station data to the WeatherLink cloud via a 4G router, located in a nearby LoRa communications enclosure.

Figure 2-3: Davis Pro weather station.

2.1.4 Static data collection

The list of static data parameters required to determine the KPIs are listed in Table 2-3. This static data collection should be completed during the initial site audit and should be repeated periodically during site visits as indicated in the table.

2.1.5 Monitoring equipment layouts and lists

The following pages constitute the package of schematics and tabled lists of monitoring systems, including:

- Single line diagram of site electrical generation, distribution, and metering (see Figure 2-4)
- Monitoring system network diagram (see Figure 2-5)
- Monitoring system specifications and legend (See Table 2-1)
- Device location plans (see Figure 2-6 to Figure 2-8)
- Monitoring parameter list (Table 2-2)
- Static data collection list (Table 2-3)

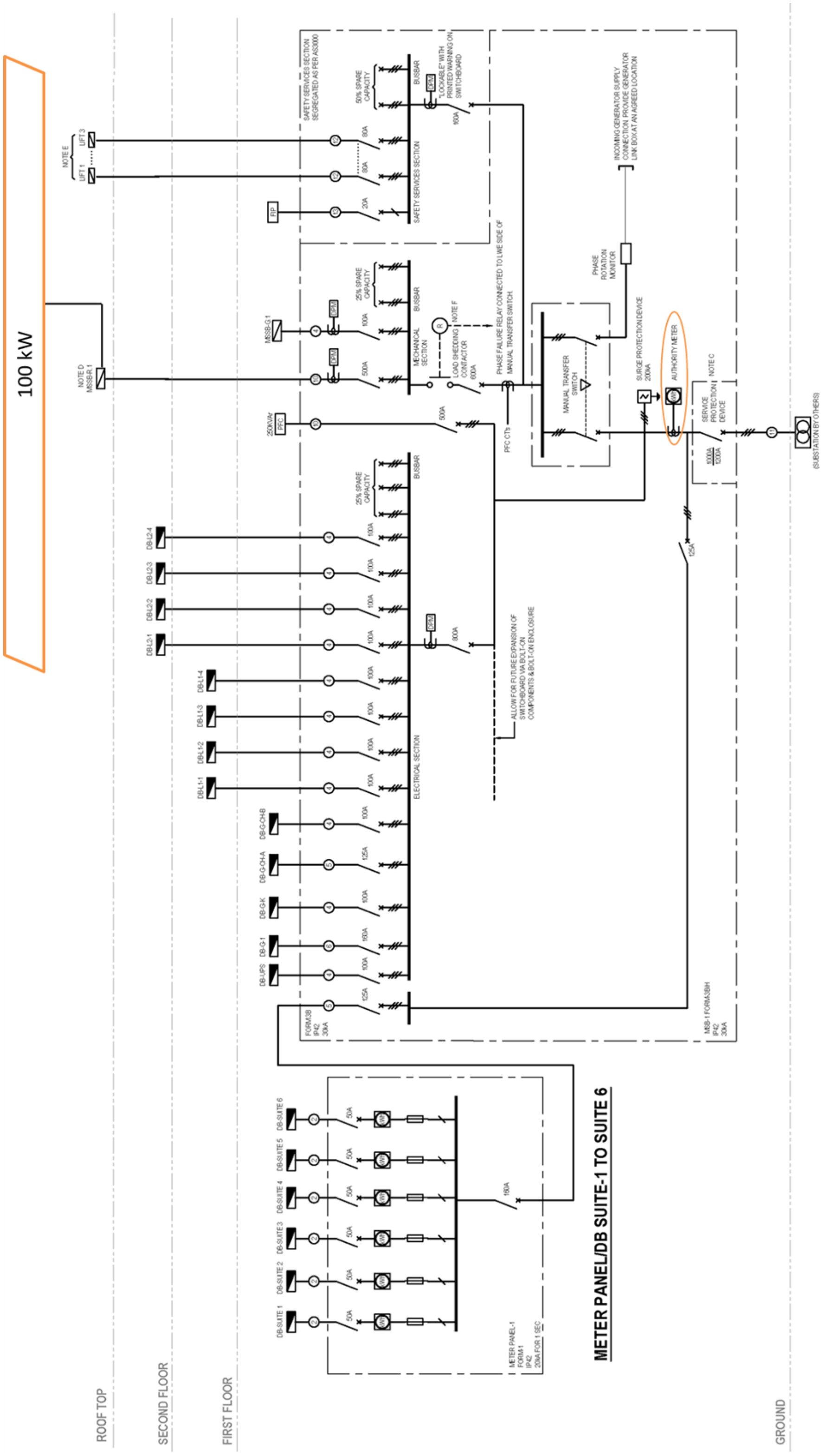


Figure 2-4. Single line diagram of site electrical generation, distribution, and metering.

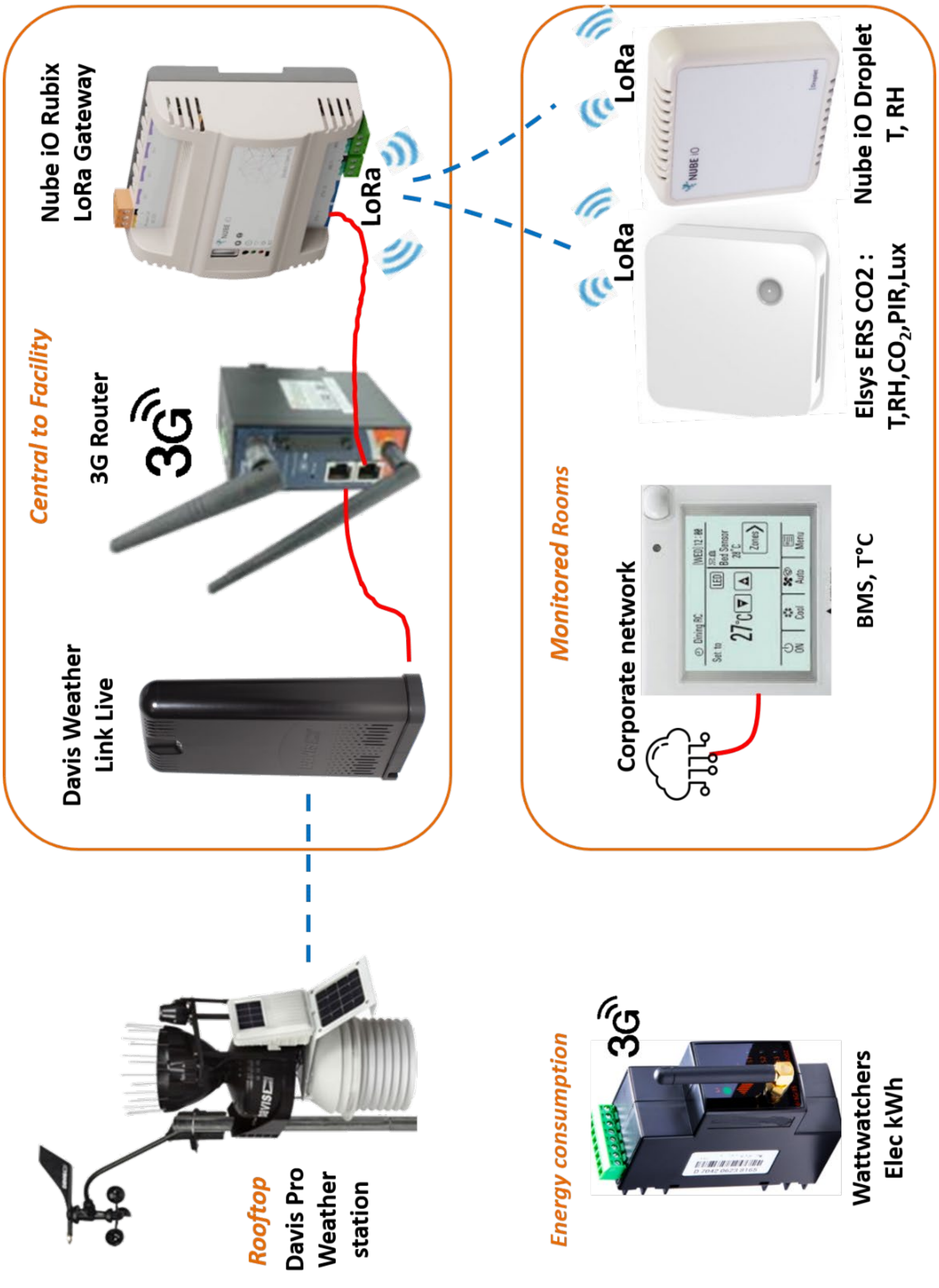


Figure 2-5. Monitoring system network diagram.

Table 2-1. Monitoring device specifications and legend.

Symbol	Parameter description	Brand/Model	Photo	Parameters measured	Comms	Wireless range	Connection limits	Sample period	Battery life or power	Comments, accessories required
E	Electricity consumption	Wattwatchers / Auditor 6M		$E_{elec\ gross}$ (kWh - also V, A, kVA, PF, and more)	3G - Wattwatchers cloud - API	3G network coverage	Unlimited devices	5 min	Hard wired	External antenna available
TH	IEQ basic	Nube IO/ Droplet DL-TH		$T_{A,B}$ $RH_{A,B}$	LoRa private network - API	70 x 70 m x 3 storey building;	100 devices per gateway	15 min	5+ year battery	Rubix LoRa Gateway
IEQ	IEQ detailed	Elsys / ERS CO2		$T_{A,B}$ $RH_{A,B}$ $CO_{2\ A,B}$, Motion, Light	LoRaWAN network - API	70 x 70 m x 3 storey building;		15 min	5+ year battery	Rubix LoRa Gateway with LoRaWAN chipset
RATH	Window opening	Elsys / EMS		Open/closed Count $T_{A,B}$ $RH_{A,B}$ $Accel_{x,y,z}$	LoRaWAN network - API	70 x 70 m x 3 storey building;		15 min	5+ year battery	Rubix LoRa Gateway with LoRaWAN chipset
T	Temperature - existing BMS			$T_{A,B}$		Hard-wired				
	Weather station	Davis		T_{out} RH_{out} GHI V_{wind} Dir_{wind} Rain PM 2 5 $_{out}$		350 m		15 min		
LoRa	Comms accessories	Nube IO / Rubix: LoRa Gateway					100 devices per gateway			

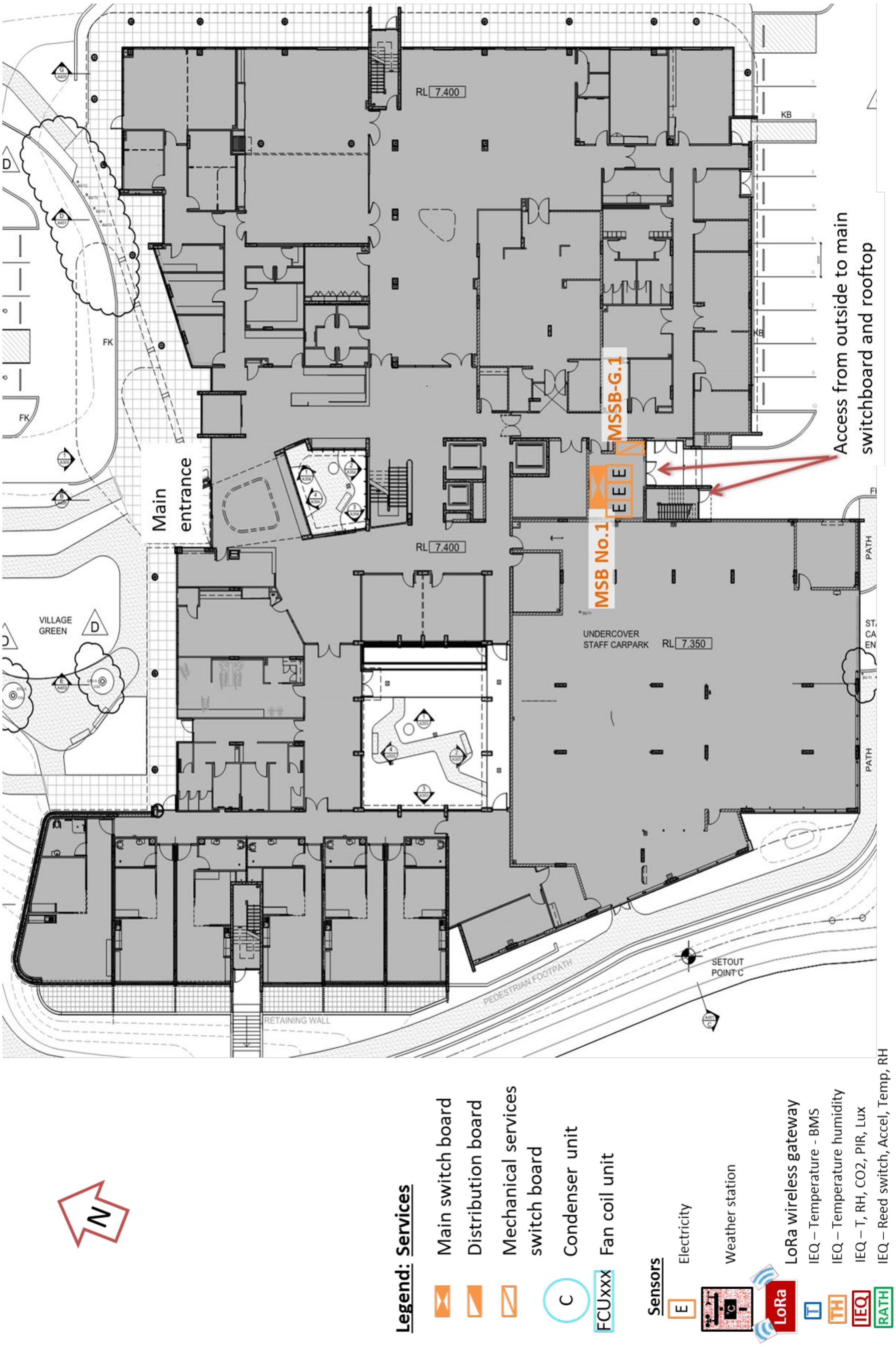


Figure 2-6: Warrigal site metering and monitoring ground level layout.

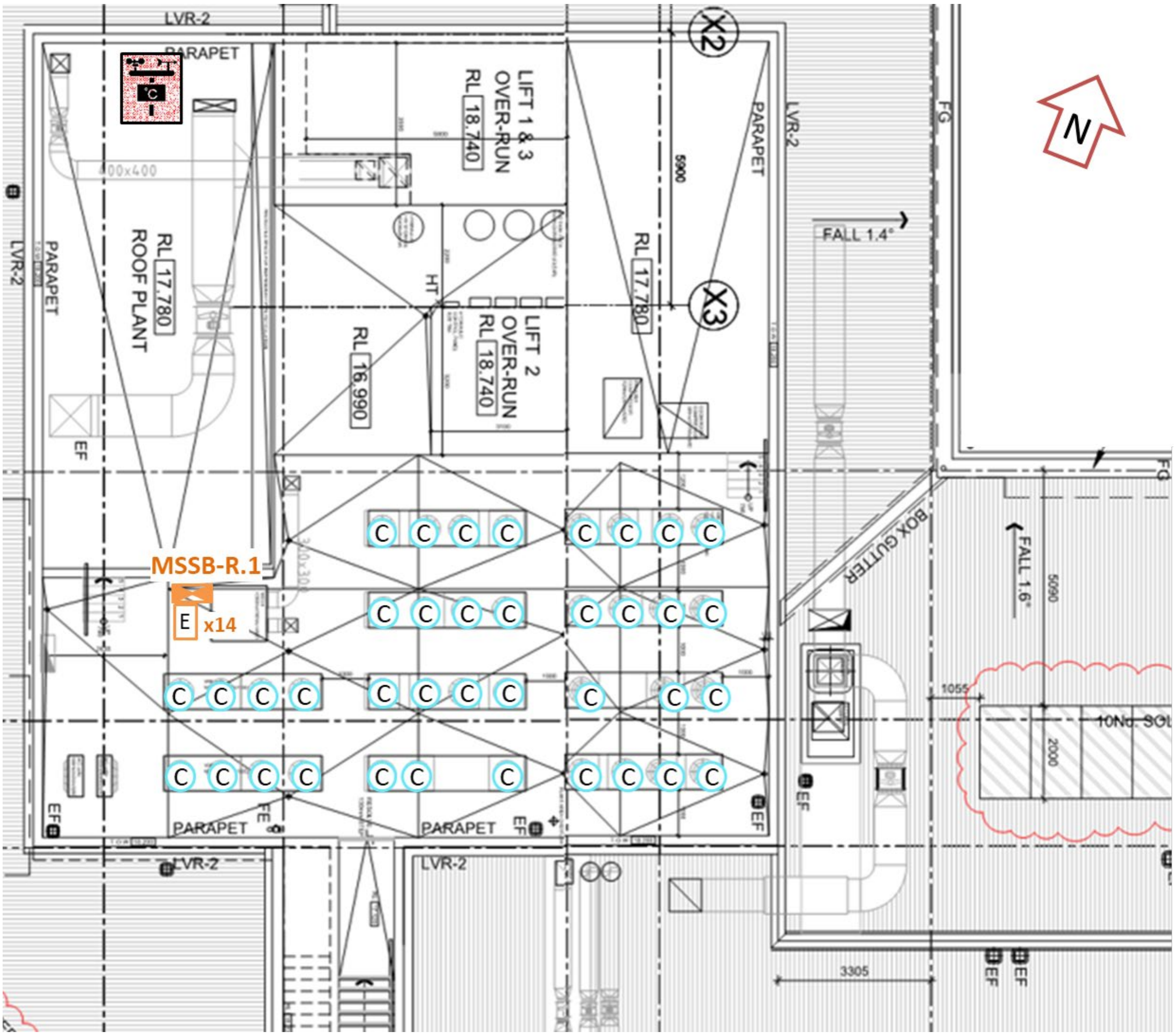


Figure 2-7: Rooftop mechanical services and monitoring layout.

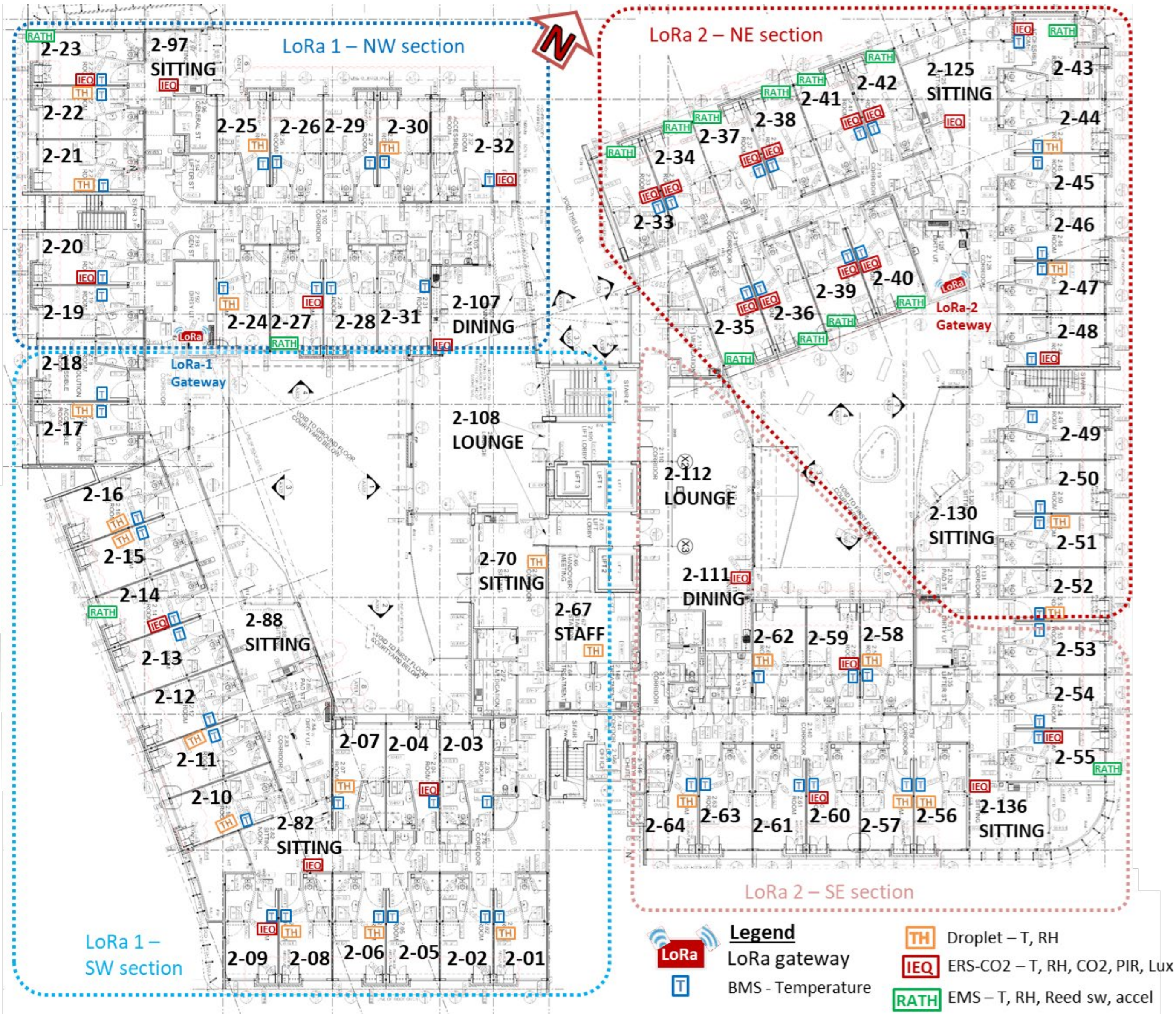


Figure 2-8: The Quay Level 2 northeast corner – detailed room monitoring layout.

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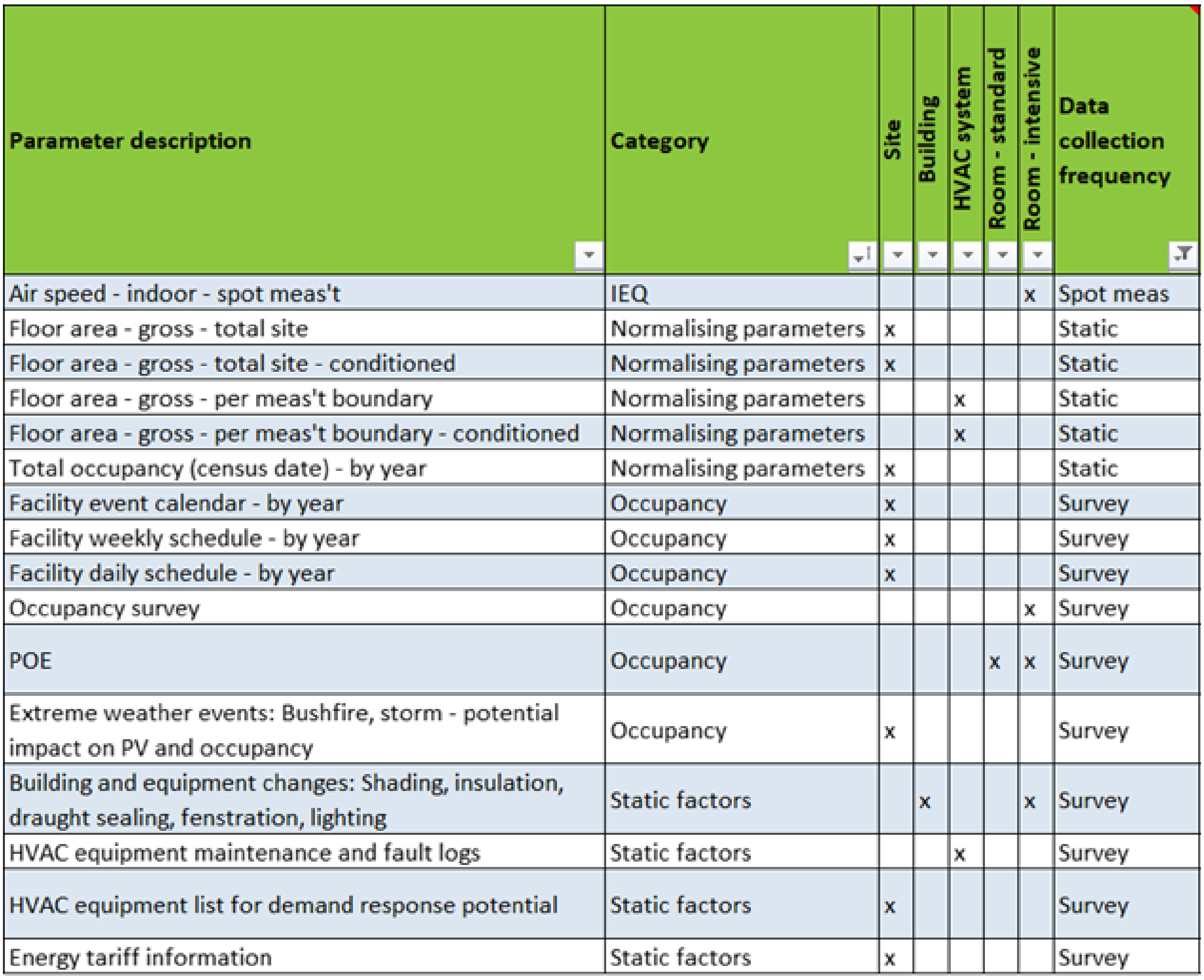
Table 2-2: Warrigal monitoring list – by data parameter

Symbol	Description	Units	Quantity	Location	Sample period and remote/local
	Site monitoring				
$E_{\text{elec gross}}$	Electricity gross site demand	*kWh*	1	MSB 1 - Ground	15-min smart meter
$E_{\text{PV gross}}$	PV gross generation	*kWh*	1	MSSB - Roof	15 min logger
T_{out}	Temperature outdoors	*°C*	1	Weather station	15 min logger
RH_{out}	Relative humidity outdoors	*%RH*	1	Weather station	15 min logger
GHI	Global Horizontal Irradiance	W/m^2	1	Weather station	15 min logger
V_{wind}	Wind speed	*m/s*	1	Weather station	15 min logger
Dir_{wind}	Wind direction	*Deg*	1	Weather station	15 min logger
Rain	Rainfall	*mm*	1	Weather station	15 min logger
	HVAC system monitoring				
$E_{\text{HVAC-G.1}}$	Total Mech Services load at MSSB-G.1	*kWh*	1	MSB 1 - Ground	5 min logger
$E_{\text{HVAC-R.1}}$	Total Mech Services load at MSSB-R.1	*kWh*	1	MSB 1 - Ground	5 min logger
$E_{\text{Condsr A,B}}$	Condenser energy; Level A (=G,1,2), Group B (14 to 20)	*kWh*	*8*	MSSB-R.1 - Roof	5 min logger
$E_{\text{FCU A,B}}$	Fan coil unit - fan energy (by condenser group)	*kWh*	*15*	MSSB-R.1 - Roof	5 min logger
$E_{\text{EXH A,B}}$	Energy consumed by supply and exhaust fans	*kWh*	*41*	MSSB-R.1 - Roof	5 min logger
$E_{\text{Apart A}}$	Ground floor serviced apartments total (separately metered)	*kWh*	*6*	MSB 1 - Ground	15-min smart meter
	Room-indoor monitoring				
$T_{\text{A,B}}$	Temperature indoors for building 'A', room 'B'	*°C*	53	Level 2 rooms	15 min logger
$RH_{\text{A,B}}$	Relative humidity indoors, building 'A', room 'B'	*%RH*	53	Level 2 rooms	15 min logger
$CO_{2\ \text{A,B}}$	Carbon dioxide concentration indoors	*ppm*	28	Level 2 rooms	15 min logger
$Occ_{\text{A,B}}$	Occupancy sensor		28	Level 2 rooms	15 min logger
Lux	Lighting level	*Lux*	28	Level 2 rooms	15 min logger
$F_{\text{open A,B}}$	Fenestration (window) opening	*Status, counts*	15	Level 2 rooms	15 min logger

Table 2-3: Static data parameter list.



Parameter description	Category	Site	Building	HVAC system	Room - standard	Room - intensive	Data collection frequency
Air speed - indoor - spot meas't	IEQ					x	Spot meas
Floor area - gross - total site	Normalising parameters	x					Static
Floor area - gross - total site - conditioned	Normalising parameters	x					Static
Floor area - gross - per meas't boundary	Normalising parameters			x			Static
Floor area - gross - per meas't boundary - conditioned	Normalising parameters			x			Static
Total occupancy (census date) - by year	Normalising parameters	x					Static
Facility event calendar - by year	Occupancy	x					Survey
Facility weekly schedule - by year	Occupancy	x					Survey
Facility daily schedule - by year	Occupancy	x					Survey
Occupancy survey	Occupancy					x	Survey
POE	Occupancy				x	x	Survey
Extreme weather events: Bushfire, storm - potential impact on PV and occupancy	Occupancy	x					Survey
Building and equipment changes: Shading, insulation, draught sealing, fenstration, lighting	Static factors		x			x	Survey
HVAC equipment maintenance and fault logs	Static factors			x			Survey
HVAC equipment list for demand response potential	Static factors	x					Survey
Energy tariff information	Static factors	x					Survey

2.2 Baseline living laboratory performance characterisation

2.2.1 Summary Energy Data Analysis

The following section presents a summary of energy consumption at the Warrigal Shell Cove residential aged care (RAC) facility. Sub-meter energy consumption data form the level 2 living laboratory was available for the period 22 August 2020 to 18 May 2021. Utility billing data was available from 1 July 2018 to 1 January 2021.

The breakdown of site energy sources (Figure 2-9) and the average monthly energy consumption (Figure 2-10) are calculated form historic utility billing data. It can be seen that electricity is the dominant energy source. Gas is used for hot water heating, cooking and laundry services; gas is not utilised for space heating. It must be noted the 99 kWp array on this site is net metered, and therefore the energy consumption breakdown shown is offset by this generation. The monthly energy breakdown shows expected rises in electricity consumption for heating in winter and a lesser rise in energy consumption for cooling in summer.

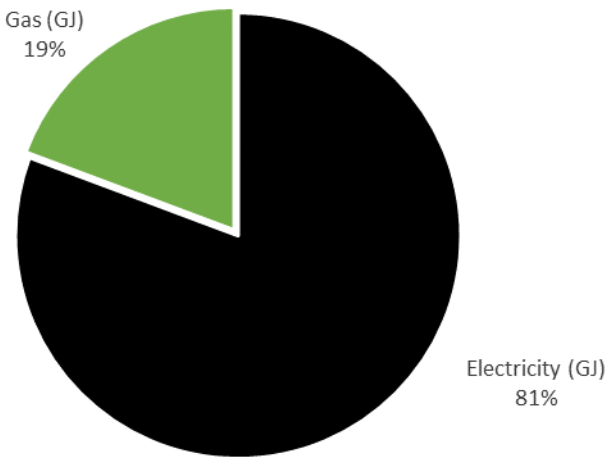


Figure 2-9. Breakdown of site energy use from historic utility billing data (2018 – 2020) for the full Shell Cove RAC site.

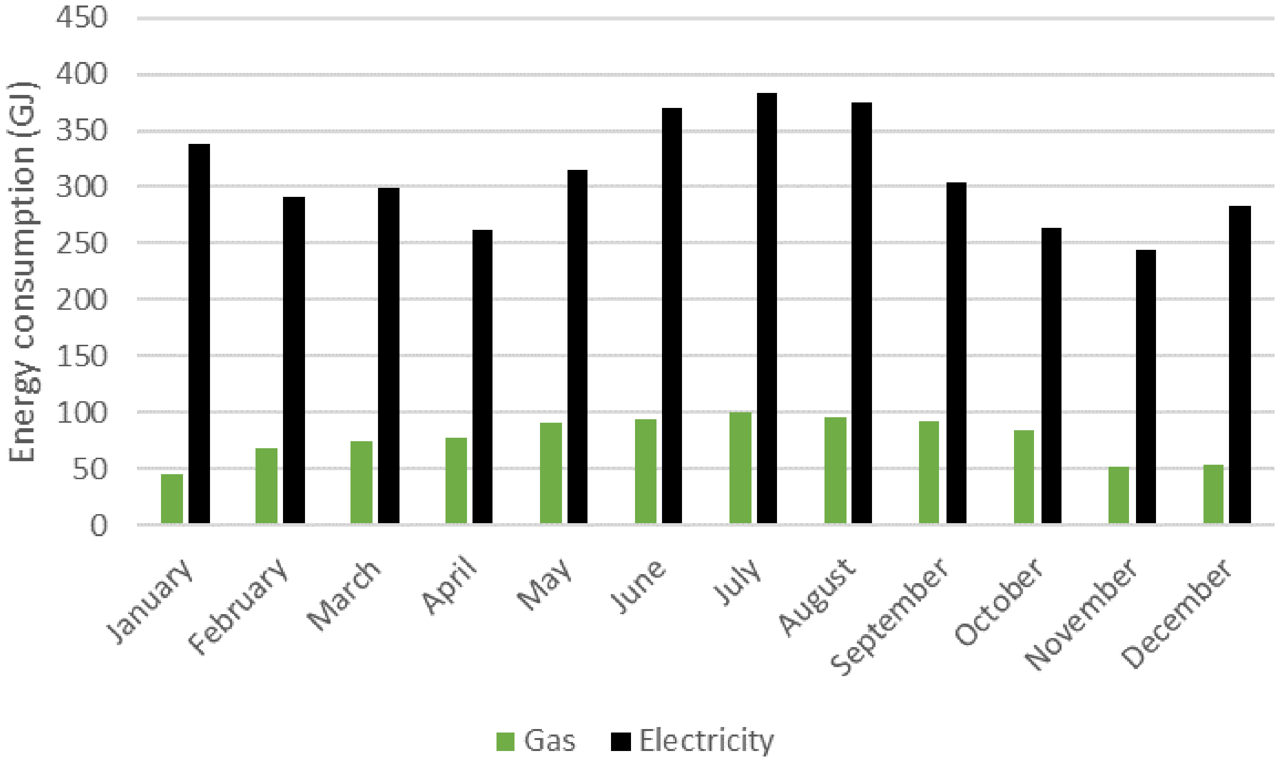


Figure 2-10 – Average monthly energy consumption for Warrigal Shell Cove RAC from 2018 – 2020.

The current baseline report presents detailed analysis of monitored energy data for the living laboratory, which is all of Level 2 of the three-level building (Ground, Level 1 and Level 2). For Level 2, the end use breakdown is shown in Figure 2-11, HVAC consumed just over half of the total consumption of the floor (53%); common area HAVC accounted for 32% of consumption and bedroom HVAC accounted for 21%, general power accounted for the remaining 48%. The higher HVAC energy consumption for the common areas compared to bedroom HVAC energy consumption is despite the floor area of the bedrooms being substantially greater than the common areas. This may be partially explained by the ventilation design for Level 2, where bedroom ventilation design is based upon natural ventilation, but in practice is largely driven by the approximately 70 continuously operating bathroom exhausts in all the bedrooms. The central dining and lounge area HVAC systems introduce 100% outside air in order to balance the pressure loss from the toilet exhausts, so the temperature differential across these indoor units is substantially increased, Corridor ventilation is provided through energy recovery ventilators, which also introduce outside air but with balanced pressure and minimal heating/cooling energy (both latent and sensible) loss through the exhaust.

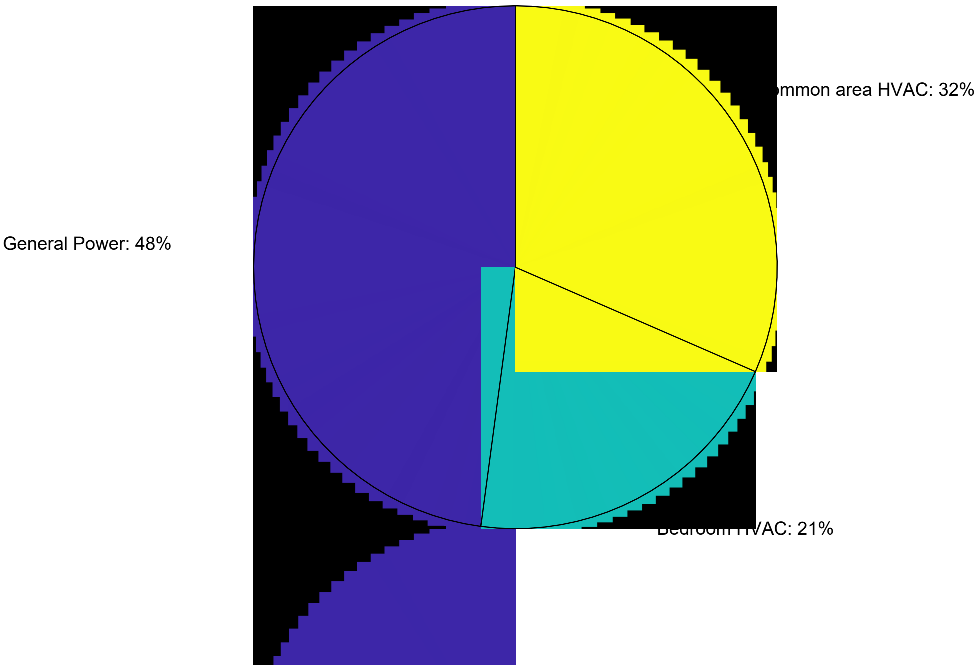


Figure 2-11. Level 2 energy consumption breakdown, showing proportion of energy use for general power, common area HVAC and bedroom HVAC.

2.2.2 Baseline REETSEF Data Analysis

REETSEF KPI 1. Avoided GHG emission (tCO_2-e and $)

CO_2-e is the sum of GHG emission for all fuel sources in use at the site and was calculated as per the National Greenhouse Accounts Factor method for fuel combustion (gas) or scope 2 emissions electricity. Gas is not used for heating within the RAC, therefore only the scope 2 emissions from electricity were considered, using the emissions intensity factor of 0.81 kg CO_2-e/kWh. Baseline CO_2-e emissions have been calculated using Wattwatchers data for the level 2 living laboratory, as shown in Table 2-4.

Table 2-4. KPI 1 - Avoided GHG emission.

	Sep 2020	**Oct 2020**	**Nov 2020**	**Dec 2020**	**Jan 2021**	**Feb 2021**	**Mar 2021**	**Apr 2021**
GHG emissions (t CO2-e)	38.9	36.2	33.4	35.6	36.0	32.8	35.7	35.8
GHG emissions intensity (kg CO_2-e/bed)	608.3	566.2	522.5	556.1	563.1	512.6	558.3	558.8
GHG emissions intensity (kg CO_2-e/m^2)	12.1	11.3	10.4	11.1	11.2	10.2	11.1	11.1
Social cost of GHG emissions[1]	$1,894	$1,762	$1,626	$1,731	$1,753	$1,596	$1,738	$1,739

REETSEF KPI 2. Avoided air pollution

The social benefit due to avoided air pollution puts a cost value to air pollution (PM_{10}, NO_x, and SO_2) impacting populations close to power station. The calculation applies a damage benefit to each MWh[2] of energy saved of $13.8/MWh for electricity. Baseline cost of air pollution for this site is provided in Table 2-5.

Table 2-5. KPI 2 – Avoided air pollution.

	Sep 2020	**Oct 2020**	**Nov 2020**	**Dec 2020**	**Jan 2021**	**Feb 2021**	**Mar 2021**	**Apr 2021**
Electricity consumption (GJ)	173.0	161.0	148.6	158.2	160.2	145.8	158.8	158.9
Cost of air pollution	$663	$617	$569	$606	$613	$558	$608	$609

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[1] Conversion from emission (tCO_2-e) to societal benefit ($) uses an estimated social cost of carbon of AUD$48.60/t$CO_2$ as a conversion factor from http://www.climateinstitute.org.au/verve/_resources/TCI_SocialCostOfCarbon_PolicyBrief_September2014.pdf. This is slightly higher than the current price of carbon with the EU ETS (AUD $41.8)

[2] https://apo.org.au/sites/default/files/resource-files/2009/03/apo-nid4196-1189331.pdf

REETSEF KPI 3. Peak 30 minute electricity demand

Peak demand for the level 2 living laboratory site was calculated as the highest 30 min electricity demand. Peak demand will be reported monthly, seasonally and annually (i.e. highest 30 min consumption per month, seasons, year), however, given the short monitoring period for the initial baseline report, only monthly peaks are shown. It can be seen that summer peak electrical demand typically occurs late in the afternoons during the hot summer months, consistent with grid peak demands from HVAC cooling energy towards the end of very hot days when residents are home and wanting to cool down at the end of a hot day. No winter data was available, but the peak demand in September and October were typical of winter peak demand in the mornings around the time when residents are getting moving for the day.

Table 2-6. KPI 3 – Peak 30 minute electricity demand.

Year	Peak 30 minute demand (kWh/30 min)	Occurrence
Sep-20	49.6	6/09/2020 8:30
Oct-20	48.5	27/10/2020 7:30
Nov-20	60.5	28/11/2020 17:00
Dec-20	50.8	1/12/2020 17:00
Jan-21	53.4	24/01/2021 17:00
Feb-21	49.3	5/02/2021 16:30
Mar-21	49.6	13/03/2021 16:00
Apr-21	47.6	5/04/2021 16:30

REETSEF KPI 4. Peak 30 minute electricity export

Access to interval utility billing data is still in the process of being obtained, and a direct request to the distributor will be required. In the absence of this data it is not possible to calculate KPI 4. Analysis of monthly utility billing data does not indicate any energy credits applied, suggesting the PV is fully utilised onsite, and no substantial exports are anticipated.

REETSEF KPI 5. Wholesale cost of peak 30 minute electricity demand

To determine whether the living laboratory peak demand was coincident with periods of energy market peak demand, the wholesale cost of peak demand at the time of occurrence was calculated using historic coincidental wholesale spot prices from AEMO[3]. The periods of peak demand, and coincident wholesale prices are shown in Table 2-7.

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[3] https://aemo.com.au/energy-systems/electricity/national-electricity-market-nem/data-nem/aggregated-data

Table 2-7. KPI 5 - Wholesale cost of peak 30 minute electricity demand.

Year	Peak 30 minute demand (kWh)	Occurrence	Coincident wholesale price (c)	Percentile of monthly wholesale cost rank
Sep-20	49.6	6/09/2020 8:30	30.87	15%
Oct-20	48.5	27/10/2020 7:30	77.08	92%
Nov-20	60.5	28/11/2020 17:00	75.82	93%
Dec-20	50.8	1/12/2020 17:00	20.86	3%
Jan-21	53.4	24/01/2021 17:00	117.08	99%
Feb-21	49.3	5/02/2021 16:30	39.95	91%
Mar-21	49.6	13/03/2021 16:00	34.94	42%
Apr-21	47.6	5/04/2021 16:30	34.08	24%

REETSEF KPI 6. Total self-consumption rate (0-1)

The self-consumption rate of renewable generation (SC) is the proportion of on-site renewable generation that is consumed on-site by the facility. Considering the 99 kWp unmetered array at Warrigal and the electricity consumption within the Level 2 living laboratory, the historic self-consumption rate, calculated at each time step in the baseline period was 99%. The monthly values are provided in Table 2-8. The average daily consumption profile, showing the average daily consumption and generation for level 2, can be seen in Figure 2-12.

Table 2-8 Warrigal KPI 6 – Total self-consumption rate

Month	Self-consumption rate
September 2020	100%
October 2020	99%
November 2020	97%
December 2020	99%
January 2021	99%
February 2021	100%
March 2021	100%
April 2021	100%

Despite the large PV array, self-consumption remains high for the level 2 living laboratory, due to the large electricity demand. The daily total electrical energy consumption profile of the Level 2 living laboratory is well matched in shape to the PV generation profile for the site. The electrical energy consumption daily profile rises earlier and peaks earlier, around 8:00 AM, when compared to the PV generation profile. Mid-afternoon when the PV generation profile is rapidly declining, the consumption profile has another peak before decaying with a lag of around 6 hours behind the PV generation decaying at 3:00 PM. The trough or plateau in consumption through the middle of the day provides an opportunity for a properly sized PV system to convert excess PV generation to cool thermal energy stores to be drawn upon later in the afternoon during grid peak demand events, when PV generation is declining. This load shifting would capture better value from a larger PV generation system on this site.

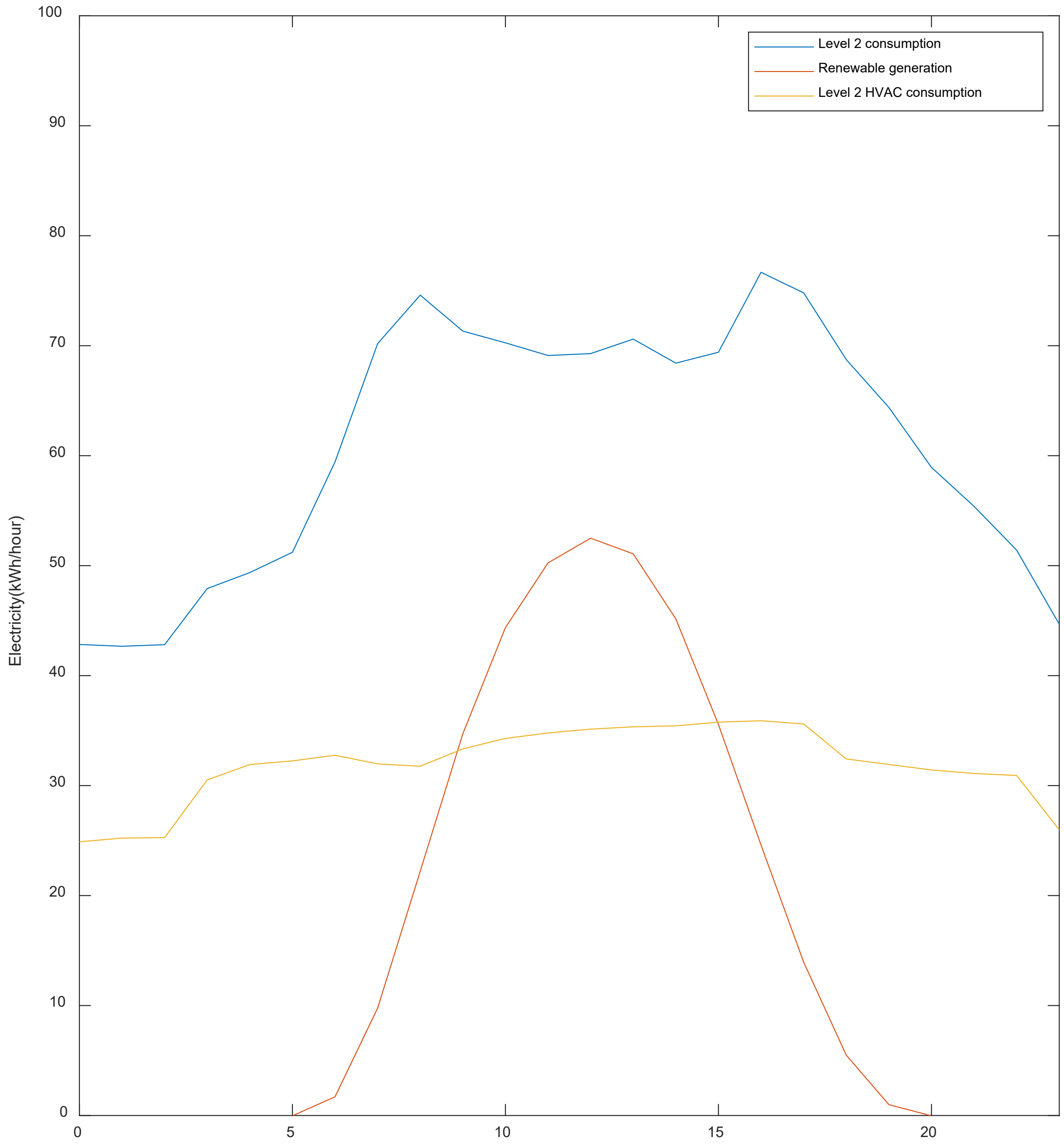

Figure 2-12. Average daily electricity profile for Level 2 living laboratory during baseline period.

REETSEF KPI 7. HVAC self-consumption rate (0-1)

Considering the 99 kWp unmetered array at Warrigal and the electricity consumption for HVAC within the Level 2 living laboratory, the historic HVAC self-consumption rate, calculated at each time step in the baseline period was 46%. The monthly values is provided in Table 2-9

Table 2-9 Warrigal KPI 7 – HVAC self-consumption rate

Month	Self-consumption rate
September 2020	42%
October 2020	45%
November 2020	45%
December 2020	52%
January 2021	51%
February 2021	50%
March 2021	45%
April 2021	42%

REETSEF KPI 8. Total renewable energy fraction (0-1)

Renewable Energy Fraction (REF) is the proportion of energy use for a facility that is generated by on-site renewable generation. Considering the 99 kWp unmetered array at Warrigal and the electricity consumption within the Level 2 living laboratory, the historic renewable energy fraction, calculated at each time step in the baseline period was 23%. The monthly values is provided in Table 2-10. This residential aged care facility operates continually, including overnight operation of the HVAC systems. So renewable energy fractions are not expected to be very high. However, renewable energy fractions around this magnitude suggest that a larger PV system may be appropriate for this site.

Table 2-10 Warrigal KPI 8 – Total renewable energy fraction

Month	Renewable energy fraction
September 2020	23%
October 2020	24%
November 2020	29%
December 2020	25%
January 2021	26%
February 2021	23%
March 2021	19%
April 2021	20%

REETSEF KPI 9. HVAC renewable energy fraction (0-1)

Considering the 99 kWp unmetered array at Warrigal and the electricity consumption for HVAC within the Level 2 living laboratory, the historic HVAC renewable energy fraction, calculated at each time step in the baseline period was 85%. The monthly values is provided in Table 2-11.

Table 2-11 Warrigal KPI 9 – HVAC renewable energy fraction

Month	Renewable energy fraction
September 2020	83%
October 2020	82%
November 2020	77%
December 2020	86%
January 2021	87%
February 2021	90%
March 2021	89%
April 2021	89%

REETSEF KPI 10. Net Facility Load Factor

Net Facility Load Factor is the average load divided by the peak load during a specified time period, and is a measure of how 'peaky' an energy use profile is. Given the short monitoring period for the initial baseline, only the total NFLF was calculated. The NFLF for the level 2 living laboratory for the period September 2020 – May 2021 was 0.50. Monthly values are shown in Table 2-12.

Table 2-12. Warrigal KPI 10 – Net facility load factor

	Sep 2020	Oct 2020	Nov 2020	Dec 2020	Jan 2021	Feb 2021	Mar 2021	Apr 2021
NFLF	0.67	0.62	0.47	0.58	0.56	0.61	0.60	0.64

The Net Facility Load Factor for the Warrigal living laboratory, with continuous automated HVAC operation throughout the day and night, is expected to be quite high, especially when compared to the ACT schools, where the facilities are unoccupied overnight and HVAC systems are switched off.

REETSEF KPI 11. Demand response capacity

There is currently approximately 258 kW of demand response capacity at Warrigal Shell Cove facility, and 104 kW of this is associated with the living laboratory on Level 2 of the building. Although the demand response capability is not currently enabled. The Mitsubishi City Multi VRF condenser units are capable of between 2 steps (0% to 100%) and 8 steps (0-25-38-50-63-75-88-100%).

As discussed above under KPI6, the site monthly peak demand in summer tends to be late in the afternoon, which is coincident with the most extreme grid peak demand events. A major contributing factor of these grid peak events are residents from working households that come home at the end of extremely hot summer's days and all turning on their AC. In contrast, this facility, and the aged care sector in general, operates the HVAC continually during the day, and with larger, centralised HVAC systems may have more incentives and opportunity to implement smarter controls to pre-cool their facilities at an earlier to time-shift the HVAC cooling load before demand response control restricts power. Existing building thermal mass or additional thermal storage may be utilised to maintain reasonable comfort during the demand response grid-controlled event.

The data discussed above, particularly under KPI 6, highlights the potential value of a demand response technology trial for this site without noticeably impacting upon thermal comfort of occupants. This clearly presents a substantial demand response opportunity at the site level, but particularly at a full property portfolio level and sector-wide level.

REETSEF KPI 12. Energy cost

Energy cost data was not available at the living laboratory level (e.g. for level 2 of the facility) Energy cost is provided in Table 2-13, calculated for the entire RAC from historic billing data for each full year for which data was available. The unit cost data will be used for assessing technology impacts at the living laboratory level in future reporting.

Table 2-13. Warrigal KPI 12 – Energy cost.

	Usage (kWh)	**Cost**	**Unit Cost**
2018	967,789.00	$211,443.00	$0.22
2019	1,069,967.00	$219,717.00	$0.20
2020	1,070,323.00	$172,237.00	$0.16

REETSEF KPI 13. Energy Use Intensity / Productivity

Energy use intensity is a measure of how much energy is used in a facility normalised for comparison with relative benchmarks. Current aged care sector EUI KPIs are typically based on kWh/bed.

Table 2-14. KPI 13 – Energy Use Intensity / Productivity.

Year	**Sep 2020**	**Oct 2020**	**Nov 2020**	**Dec 2020**	**Jan 2021**	**Feb 2021**	**Mar 2021**	**Apr 2021**
Electricity consumption (kWh/day)	1602	1443	1376	1417	1435	1447	1423	1472
Electricity intensity (kWh/m^2/day)	0.50	0.45	0.43	0.44	0.45	0.45	0.44	0.46
Electricity intensity (kWh/bed./day)	25.0	22.5	21.5	22.1	22.4	22.6	22.2	23.0

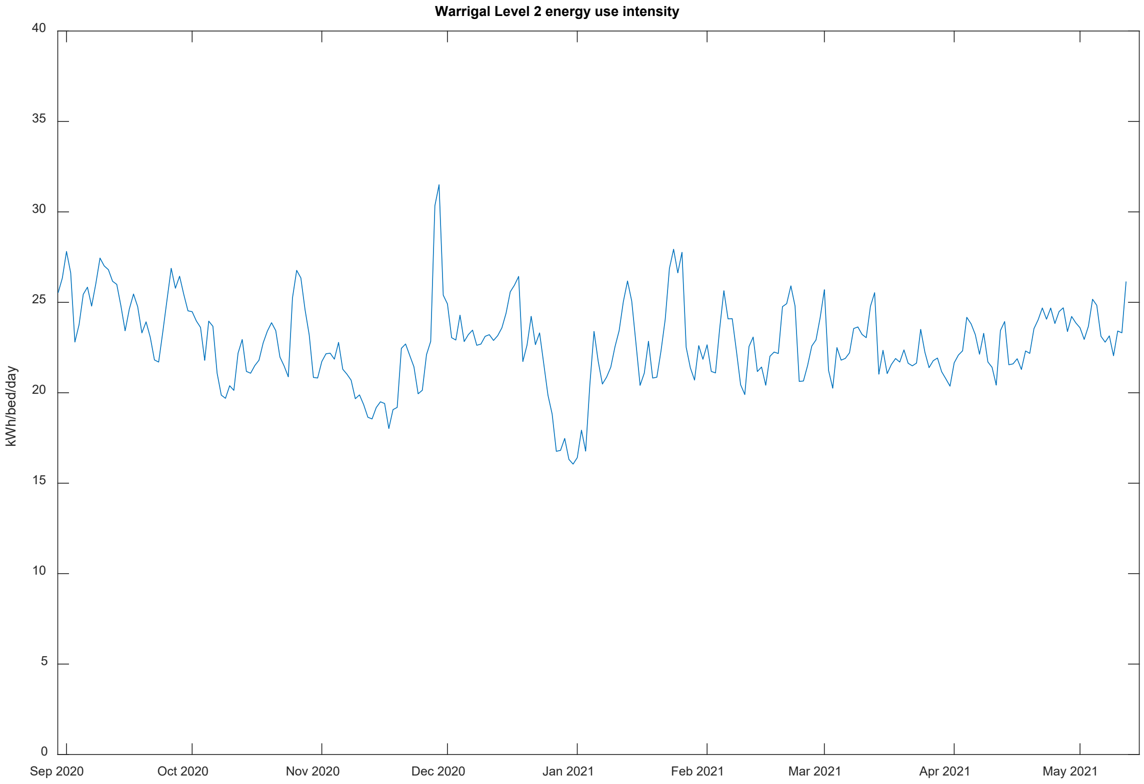

Figure 2-13. Daily per bed electricity use intensity, Warrigal Living Labs site.

2.2.3 Baseline IEQ

Baseline temperature

Data in the following sections has been analysed to determine hours above and below certain threshold temperatures. Appropriate threshold temperatures could be selected from a range of sources. No minimum provisions in regards to thermal comfort are provided by the Australian residential aged care Accreditation Standards, the current report has used the recommendations provided in Annex A of the ISO 7730:2005 Standard[4].More nuanced assessment of the thermal comfort performance of these spaces may be required for the trial technology assessments.

For the current report, temperature data has been collected for the period from 28 August 2020 to 5 May 2021. Summary statistics, and a range of visualisation of the monitored temperature data are provided in Table 2-15, Figure 2-14 and Figure 2-15. It is important to note that the baseline sample period does not include any winter data.

Table 2-15. Summary temperature statistics for Warrigal Shell Cove Residential Aged Care facility 28 August 2020 to 5 May 2021).

Room ID	Mean temp °C	Min temp °C	Max temp °C	%<20°C	%<21°C	%>24°C	%>26°C	% within threshold 21 - 24°C	% within threshold 20 - 26°C
Bedrooms									
NE 033	22.6	18.1	26.4	4.7%	12.3%	11.3%	0.1%	76.4%	95.2%
NE 034	22.7	18.2	27.8	0.5%	3.9%	8.1%	0.2%	88.0%	99.3%
NE 035	22.6	20.0	25.1	0.0%	3.7%	0.5%	0.0%	95.8%	100.0%
NE 036	22.8	18.4	25.9	0.9%	5.9%	13.3%	0.0%	80.8%	99.1%
NE 037	22.8	17.5	27.3	1.5%	6.2%	14.3%	0.3%	79.5%	98.2%
NE 038	23.0	16.3	26.2	1.0%	2.8%	22.8%	0.1%	74.4%	98.9%
NE 039	22.9	19.0	25.7	0.7%	4.6%	12.2%	0.0%	83.1%	99.3%
NE 040	22.9	19.2	25.8	1.0%	6.2%	17.6%	0.0%	76.2%	99.0%
NE 041	23.4	20.3	26.6	0.0%	0.4%	24.6%	0.1%	75.0%	99.9%
NE 042	23.2	19.1	26.5	0.2%	2.0%	21.4%	0.1%	76.6%	99.8%
NE 043	23.1	18.5	27.2	1.4%	5.6%	21.8%	0.7%	72.6%	98.0%
NE 044	22.9	18.8	27.1	1.0%	5.6%	16.8%	0.2%	77.5%	98.8%
NE 047	23.2	19.8	26.6	0.1%	2.2%	17.8%	0.1%	79.8%	99.8%
NE 048	23.3	17.8	27.5	0.3%	1.9%	25.0%	0.2%	73.1%	99.4%
NE 051	22.9	18.7	27.0	0.7%	4.7%	15.6%	0.5%	79.7%	98.9%
NE 052	23.1	18.8	26.9	0.6%	3.4%	17.7%	0.2%	78.8%	99.2%
NW 020	22.4	17.9	26.9	3.6%	12.8%	6.3%	0.3%	80.9%	96.2%
NW 021	22.6	19.9	24.7	0.0%	3.6%	0.6%	0.0%	95.8%	100.0%
NW 022	22.6	18.7	26.0	1.2%	6.4%	6.2%	0.1%	87.3%	98.7%

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[4] International Organization for Standardization, Ergonomics of the thermal environment - Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria, (2005).

NW 023	23.2	18.7	26.9	1.4%	6.3%	24.0%	2.3%	69.7%	96.3%
NW 024	24.1	20.5	26.9	0.0%	0.3%	55.3%	2.4%	44.3%	97.6%
NW 025	22.6	18.9	28.9	0.5%	4.4%	4.5%	0.1%	91.1%	99.4%
NW 027	23.0	19.5	28.6	0.5%	4.5%	19.3%	0.6%	76.1%	99.0%
NW 030	22.6	18.5	27.4	0.8%	6.0%	3.9%	0.1%	90.0%	99.1%
NW 032	22.7	17.9	33.3	3.5%	11.1%	19.9%	1.0%	69.0%	95.5%
SE 055	23.0	19.2	26.9	0.5%	3.6%	17.6%	0.2%	78.0%	99.3%
SE 056	22.4	18.4	26.7	2.2%	9.7%	6.1%	0.1%	84.1%	97.6%
SE 057	22.8	18.4	26.2	1.8%	5.8%	12.3%	0.1%	81.9%	98.1%
SE 058	23.3	19.6	26.2	0.1%	0.8%	20.8%	0.1%	78.3%	99.8%
SE 059	23.2	20.1	25.6	0.0%	0.6%	13.5%	0.0%	85.8%	100.0%
SE 060	22.8	19.1	26.0	0.5%	2.6%	8.7%	0.0%	88.7%	99.5%
SE 062	23.3	18.4	31.1	1.0%	3.9%	27.4%	0.5%	68.7%	98.5%
SE 064	22.3	19.1	27.3	0.9%	8.2%	6.6%	0.2%	85.1%	98.9%
SW 001	22.6	17.6	27.2	3.0%	12.0%	11.2%	0.2%	76.8%	96.7%
SW 004	22.8	19.0	25.9	0.3%	4.0%	6.8%	0.0%	89.2%	99.7%
SW 006	22.4	19.2	25.7	0.4%	6.8%	4.6%	0.0%	88.5%	99.6%
SW 007	23.2	19.4	26.5	0.2%	1.8%	21.8%	0.1%	76.3%	99.7%
SW 008	22.2	18.3	26.6	7.1%	23.2%	9.7%	0.5%	67.1%	92.4%
SW 009	22.4	17.7	26.3	3.1%	10.8%	7.9%	0.0%	81.4%	96.9%
SW 010	22.5	18.5	27.3	2.0%	12.8%	10.9%	0.4%	76.2%	97.6%
SW 011	22.5	18.8	26.6	1.6%	10.0%	10.9%	0.2%	79.0%	98.2%
SW 014	22.4	18.6	26.2	2.0%	11.2%	4.9%	0.0%	83.9%	98.0%
SW 015	22.4	18.7	26.4	3.2%	14.8%	10.1%	0.1%	74.9%	96.6%
SW 016	22.6	18.0	27.0	2.9%	12.3%	12.3%	0.5%	75.3%	96.5%
SW 017	22.6	18.3	28.2	1.8%	12.2%	15.5%	0.8%	72.3%	97.3%
Staff									
SW 067	23.2	19.9	27.7	0.1%	1.5%	17.9%	0.3%	80.5%	99.7%
Sitting									
SW 070	22.2	17.5	28.9	3.5%	15.2%	6.6%	0.4%	78.0%	96.0%
SW 082	22.6	18.9	26.9	0.4%	3.4%	5.4%	0.1%	91.2%	99.5%
NW 097	22.7	19.2	27.1	0.7%	4.1%	8.9%	0.3%	87.0%	99.0%
NE 125	22.4	17.9	26.4	1.5%	6.8%	4.5%	0.1%	88.7%	98.4%
SE 136	22.5	19.0	27.0	0.5%	4.1%	5.7%	0.4%	90.2%	99.1%
Dining									
NW 107	21.9	16.7	29.4	12.4%	24.3%	7.0%	0.9%	68.7%	86.7%
SE 111	21.9	16.7	29.3	8.6%	25.0%	7.9%	0.7%	66.3%	90.4%
Mean	**22.8**	**18.7**	**27.1**	**1.7%**	**7.1%**	**13.3%**	**0.3%**	**79.5%**	**98.0%**

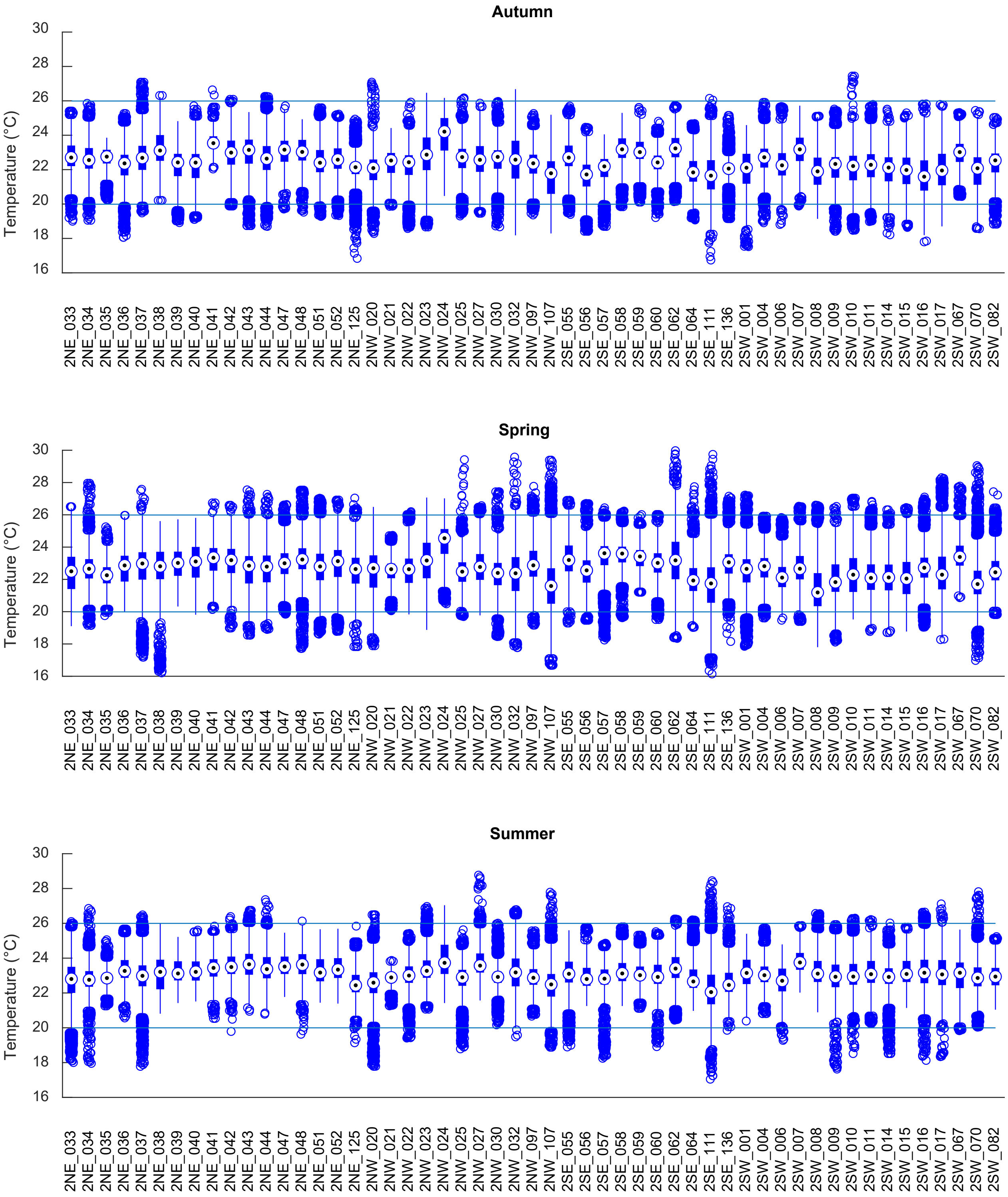

Figure 2-14. Boxplot displaying seasonal temperature variations over monitored period for each monitored room for Warrigal Shell Cove Facility.

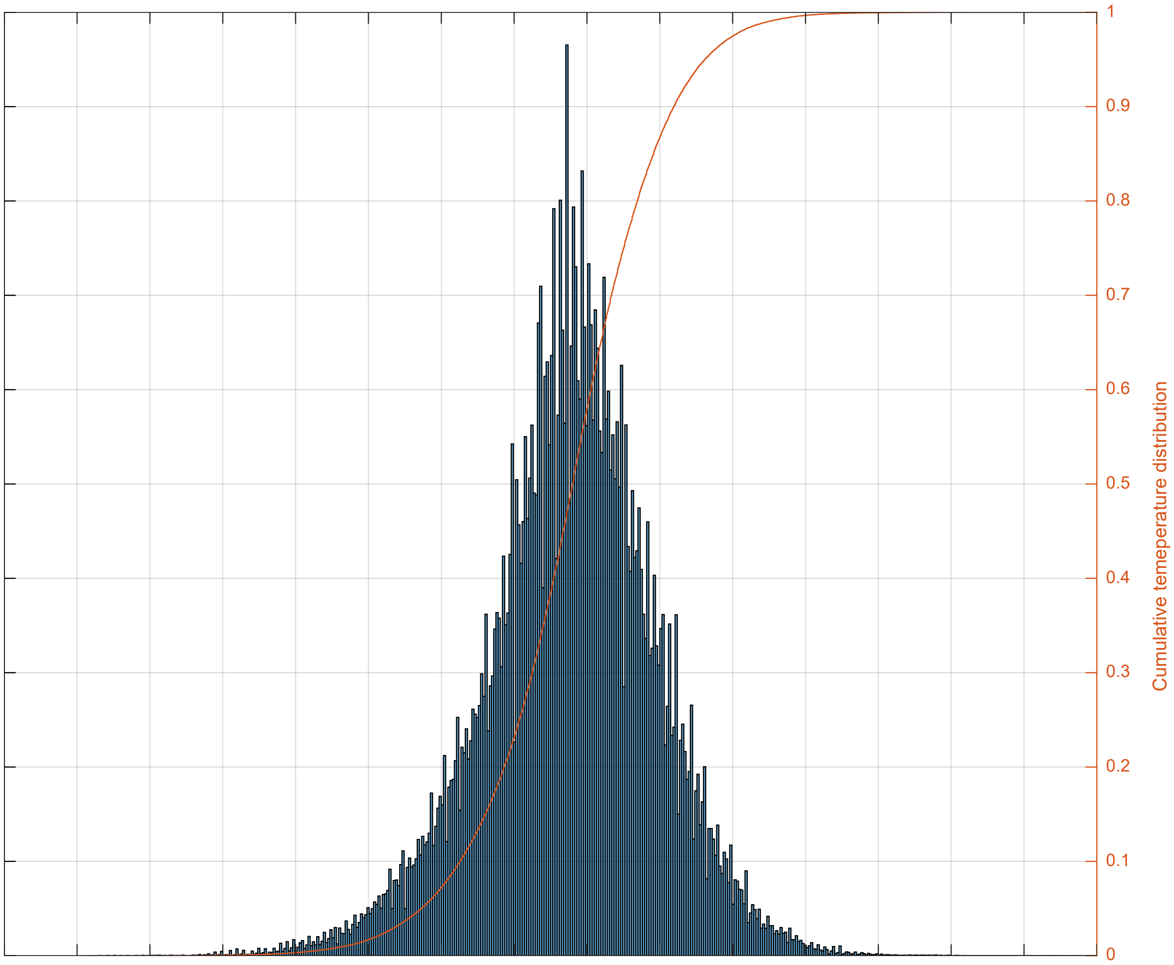

Figure 2-15. Temperature histogram and cumulative distribution for all internal temperature sensors for Warrigal Shell Cove RAC

The summary data presented in Table 2-15, Figure 2-14 and Figure 2-15 suggests, in the baseline condition the Shell Cove RAC facility has good thermal comfort. On average, the recorded temperatures were within both the wider temperature band (20 – 25 °C) and the more stringent comfort band (21 – 24 °C) for much of the monitored period (98% and 80% respectively).

The rooms in Table 2-15 have been grouped into categories for bedrooms; staff room; corridor common sitting areas; and common dining rooms. The bedroom temperature data dominate the average due to the number of bedrooms monitored. The common sitting areas, located in corridor corners, ventilated via the ERV units, are maintained within the temperature thresholds more consistently than the overall average. This is expected to be due to the centrally controlled common areas being conditioned for comfortable staff use throughout the day and night.

Against this comparison of the common area temperatures, the bedroom average temperatures are a little higher, but the variation, as indicated by percentage of time within the inner threshold is noticeably lower by around 10%. Percentage of time within the outer thresholds is still very high at 98%, suggesting that some residents are choosing their own comfort bands more broadly outside the inner thresholds but still within reasonable comfort ranges. The slightly higher average temperatures maintained in the bedrooms is consistent with these typically more sedentary spaces, occupied and individually controlled to the personal preference of the older residents.

Given there was no winter data available for the current baseline, further investigation was undertaken to understand if issues of underheating may be expected to be prevalent during cold periods. Figure 2-16 shows time series data for a number of rooms during a cold week in the baseline monitoring period. Clear evidence of heating input can be seen for NW107 and SE111 to maintain a minimum comfortable overnight temperature of around 18.5 °C, while the daytime temperature set points are around 22 °C. These two rooms are the common central dining areas. Notice the clear heating input at the end of each day, as the outdoor temperature starts to rapidly fall at sunset, around dinner time when these rooms will be expected to be well occupied. Shortly thereafter, it appears that the temperature set points are reduced to 18.5 overnight. With 100% outside air being introduced throughout the day and night, these AC units effectively preheat this outside air before it passes through the corridor spaces and drawn into the bedrooms by the toilet exhaust fans. These plots explain the dining room temperature statistics from Table 2-15, where the dining room temperatures are approximately 1 °C lower than the overall average and percentage of time within the threshold ranges are noticeably less. From the baseline data it appears the current HVAC system is able to provide appropriate thermal comfort in this facility throughout all seasons.

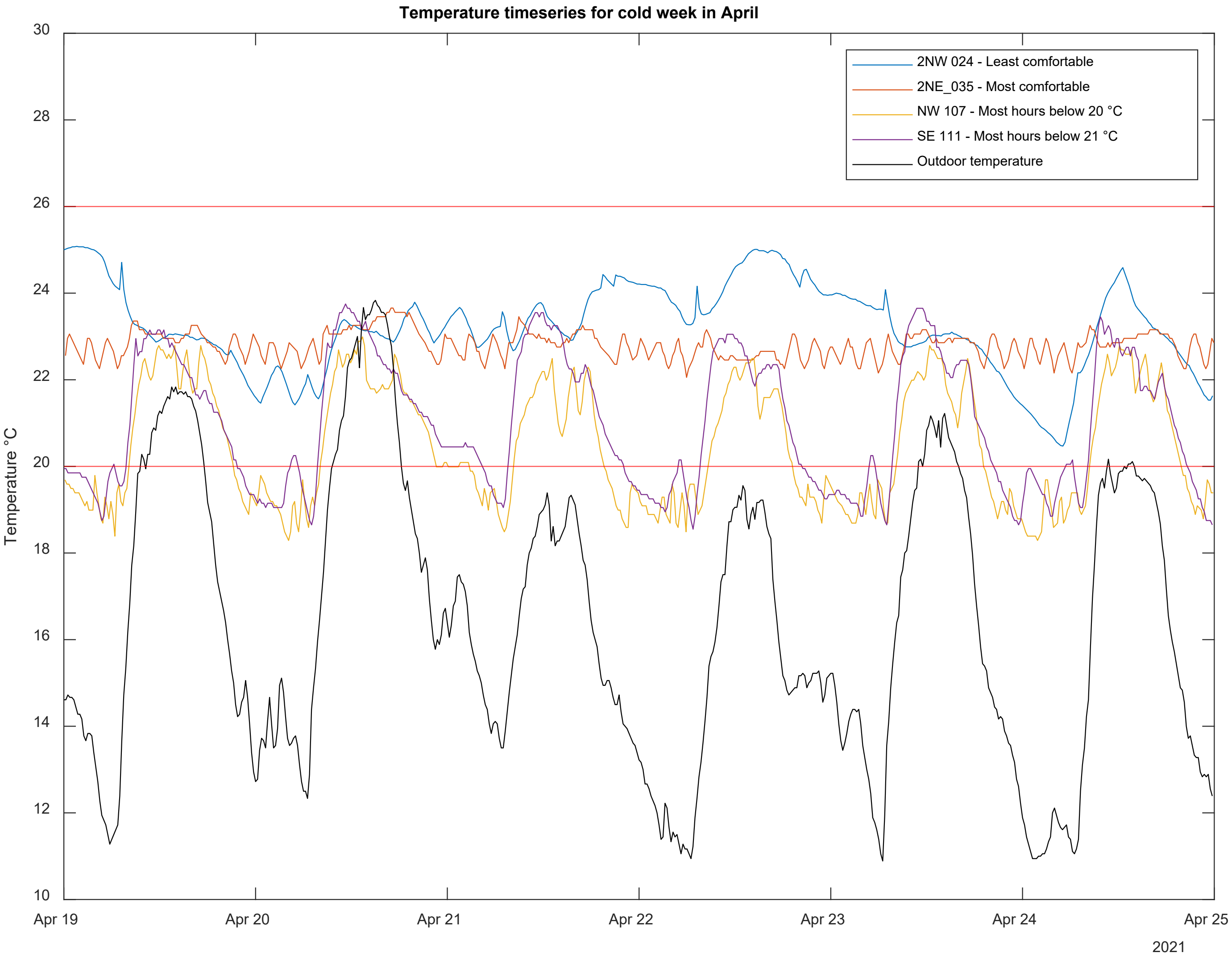

Figure 2-16. Time series temperature plot showing temperatures in the coldest room in each zone during the coldest week in the sample period.

Baseline Carbon Dioxide concentration

Concentration of Carbon Dioxide (CO_2) is often used as a readily measured proxy for indoor air quality and ventilation rates. Increased ventilation rates on a per occupant basis have been associated with reduced negative respiratory health effects. Minimum ventilation rate standards for moderate indoor air quality in are commonly around 7 l/s per occupant, AS1668.2 specifies minimum outdoor air ventilation rates of 12 L/s per occupant. CO_2 concentrations above 1000ppm are generally accepted to indicate insufficient fresh air is being introduced into a space, and occupants respiratory and cognitive function may be negatively impacted.

A summary of the monitored CO_2 concentrations for the various rooms with IEQ sensors is provided in Table 2-16. A more granular display of the CO_2 data quartiles is provided in Figure 2-17, in which it can be seen for example how prevalent the higher CO_2 values were in different spaces. It can be seen that in most cases the CO_2 levels in rooms are well below the threshold for concern. Exceptions to this general observation are bedrooms NE036 and NW027, although even these rooms have maximum CO_2 concentrations of only 1283 and 1340 ppm.

Table 2-16. Summary Carbon Dioxide concentration statistics for Warrigal Shell Cove Facility

Device	Mean	Max	Data points over 800 ppm	Data points over 1000 ppm	Days with max hourly mean CO_2 reading over 800 ppm	Days with max hourly mean CO_2 reading over 1000 ppm
NE 033	478	1189	0.3%	0.0%	6.7%	0.4%
NE 034	516	1345	0.8%	0.0%	33.8%	1.3%
NE 035	569	1384	1.2%	0.2%	24.2%	4.6%
NE 036	565	1283	5.5%	1.1%	51.2%	19.6%
NE 037	528	1445	2.1%	0.1%	46.3%	4.2%
NE 038	539	952	0.4%	0.0%	9.2%	0.0%
NE 039	543	1030	3.9%	0.0%	59.9%	2.4%
NE 040	527	1043	3.2%	0.0%	51.7%	1.3%
NE 041	501	938	0.2%	0.0%	4.5%	0.0%
NE 042	533	1848	0.2%	0.0%	10.4%	0.4%
NE 043	516	1280	0.1%	0.0%	2.1%	0.4%
NE 048	511	1166	0.9%	0.1%	10.8%	2.5%
NE 125	454	666	0.0%	0.0%	0.0%	0.0%
NW 020	535	1579	1.6%	0.0%	27.6%	0.8%
NW 023	493	1200	0.0%	0.0%	1.7%	0.4%
NW 027	689	1340	26.9%	5.8%	90.9%	39.2%
NW 032	513	890	0.0%	0.0%	2.5%	0.0%
NW 097	457	637	0.0%	0.0%	0.0%	0.0%
NW 107	470	1965	0.0%	0.0%	1.2%	0.8%
SE 055	522	907	0.2%	0.0%	4.6%	0.0%
SE 059	483	1034	0.0%	0.0%	3.3%	0.4%
SE 060	485	882	0.0%	0.0%	1.7%	0.0%
SE 111	463	809	0.0%	0.0%	0.4%	0.0%
SE 136	466	741	0.0%	0.0%	0.0%	0.0%
SW 004	501	983	0.0%	0.0%	2.5%	0.0%
SW 009	508	965	0.6%	0.0%	14.6%	0.0%
SW 014	499	1110	0.7%	0.0%	23.0%	0.8%
SW 082	460	675	0.0%	0.0%	0.0%	0.0%

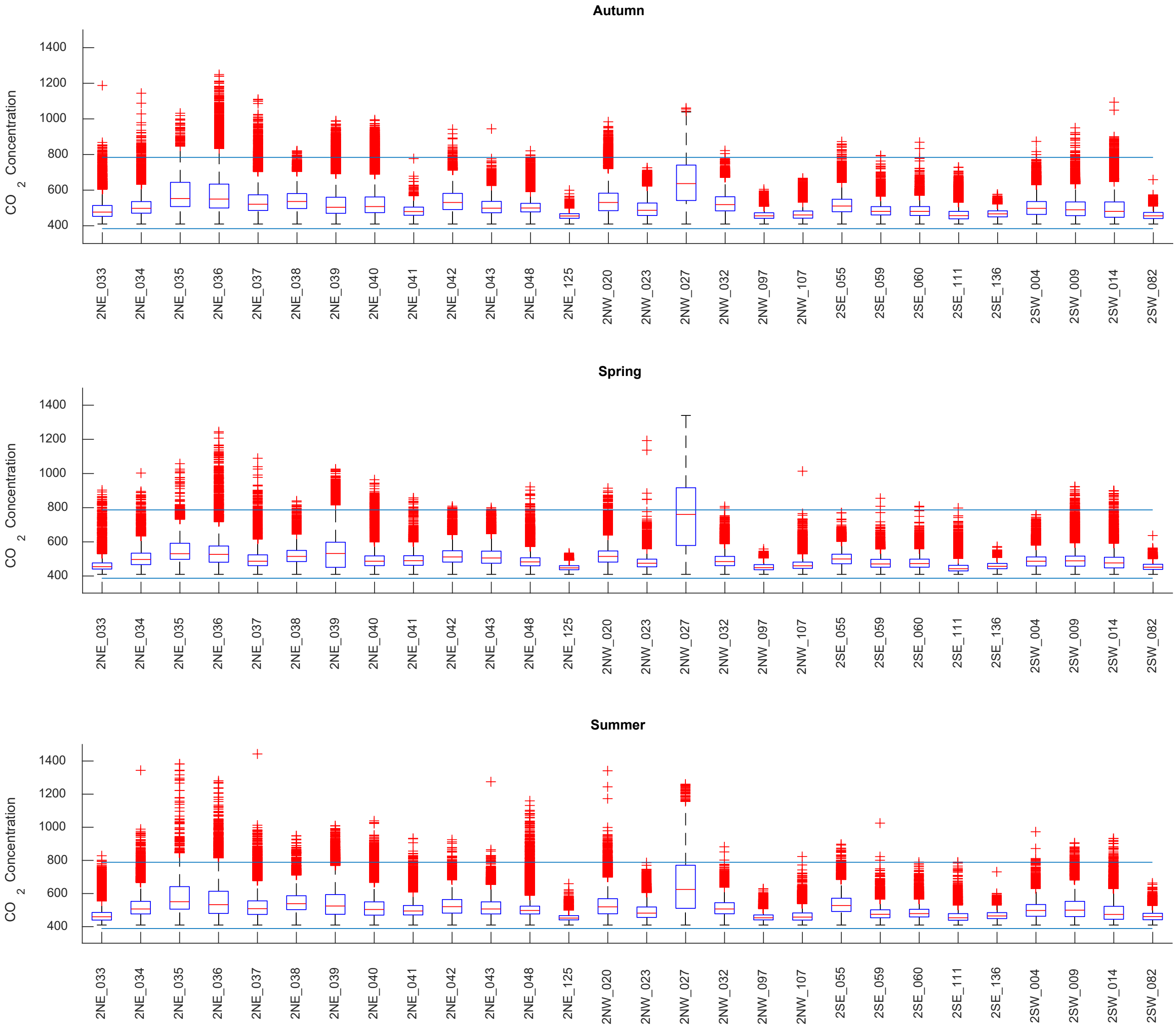

Figure 2-17. Boxplot showing summary Carbon Dioxide concentration statistics for individual rooms in Warrigal Shell Cove Facility

A time series showing a week for the two worst performing rooms is provided in Figure 2-18. It can be seen that most of the periods with over 1000 ppm occur during the overnight period, with clear spikes around midnight for NE036. The bathroom exhaust fans were described as continual operation, however this data suggests that these fans, which are the only mechanical means of supplying fresh air to individual rooms, are switched off around 11:00 pm and switched back on around 3:00 am.

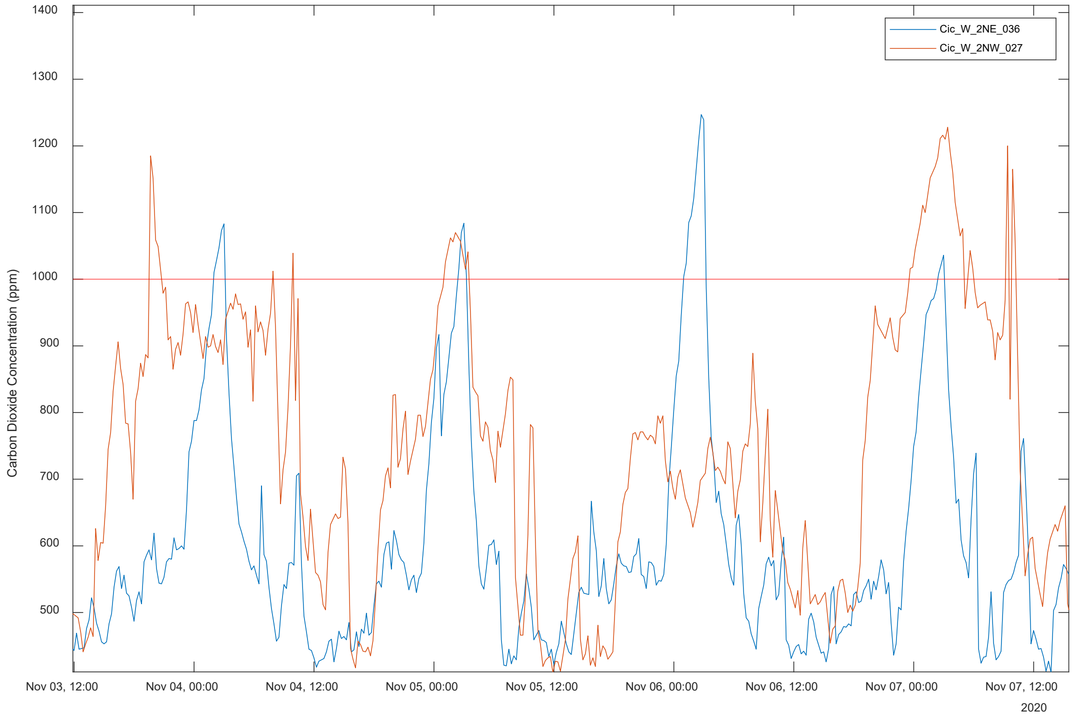

Figure 2-18. Time series carbon dioxide for worst performing rooms.

3 CONCLUSION

The current baseline report has provided a brief introduction to the Warrigal Shell Cove Facility, provided detail of the living laboratory monitoring systems installed, and summarised the baseline performance of the facility.

A comprehensive monitoring system has been deployed in Level 2 of the RAC facility, allowing flexible evaluation of the impact of a range of innovative renewable energy and enabling technologies and services. Key data sources include in-room monitoring of temperature, relative humidity, and carbon dioxide (for a subset of rooms), monitoring of local conditions via a rooftop weather station, and sub-metered electricity consumption.

The baseline performance of the living laboratory has also been assessed, according to the Renewable Energy and Enabling Technology and Services Evaluation Framework (REETSEF) developed though iHub. The REETSEF evaluation has summarised information about the current performance of the facility according to indicators relevant to social benefits, network benefits, and benefits to the provider. The baseline IEQ of the facility has also been assessed, based on monitored conditions.

Considering the REETSEF KPIs, the lack of effective benchmarking data makes it difficult to comment on the baseline performance of the facility, relative to other facilities (i.e. considering societal and sector benefits). Considering the KPIs related to network benefits, it is clear that the facility can benefit from implementation of load shifting and/or demand response. Peak consumption occurs in the afternoons, and in summer particularly, is co-incidental with grid peak events. The self-consumption rate for Level 2 for the large solar array is very high, approaching full utilisation, and as such the average daily profile show a typical duck curve. The HVAC self-consumption rate for Level 2 is much lower, and the average daily profile shows only modest changes in consumption throughout the day. This suggests that opportunities may exists for innovative controls (e.g. model predictive control) that can better align HVAC consumption with periods of solar generation (i.e. through pre-conditioning of thermal mass). Finally, whilst no demand response is currently enabled within the facility, the installed condenser units are demand response capable, potentially providing demand response capacity of 258 kW for the site, or 104 kW for Level 2.

The baseline report has found that thermal comfort is being delivered to an acceptable standard, and therefore that the existing, relatively modern, HVAC equipment is fit for purpose. A small number of rooms have slight issues with elevated CO_2 concentrations, however these do not reach high enough levels to be of pressing concern. Internal temperature variation in rooms appear to be in responses to set point variations, and in general, conditions are acceptable.

In light of these findings, it appears that there is potential for innovative HVAC technology and controls to be implemented in the living laboratory, with a focus on reducing peak demand and enabling demand response. From the baseline assessment and discussions with the facilities management, it is expected that there is some flexibility to load-shift HVAC demand, whilst maintaining comfort at appropriate standards within the facility.