The Innovation Hub

for Affordable Heating and Cooling

Final Sub-Project Knowledge Sharing report

Warrigal Residential Care Home Living Laboratory Final Report – Technology Evaluation and Operation Analysis

Project – LLHC2

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The 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.

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Final Sub-Project Knowledge Sharing Report

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1. Sub-Project Overview, Objectives and Importance to Market/Industry

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.

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1.2. Warrigal Residential Care Home Living Laboratory

A 'Living laboratory' is a user-centred open-innovation, ecosystem within collaborative partnerships. Living Laboratories benefit both technology providers and technology users, addressing barriers to the uptake of innovation, such as lack of familiarity, risk aversion and distrust in supplier claims. The i-Hub Living Laboratories are flexible spaces where product suppliers can bring their technology for independent validation.

The Warrigal Shell Cove living laboratory establishes research-quality measurement and verification systems within an existing aged care facility, to monitor HVAC services and occupant behavioural impact on indoor environmental quality (IEQ) in order to observe and evaluate technology upgrades within the context of the daily life of these aged care ecosystems. The technologies trialled in this living laboratory were selected from promising electric heating and cooling strategies and passive design features that increase the energy flexibility of aged care facilities, and deliver increased value for renewable energy, at the site and grid level.

The Warrigal Shell Cove living laboratory is a three-level residential care home opened in 2017, with a gross floor area of 9171 m2, including 126 beds, 6 serviced apartments and a number of shared spaces. The facility includes a large 99kWp array of solar panels and a series of heat recovery VRF (variable refrigerant flow) heat pump systems serve the buildings heating and cooling needs.

1.3. Living Laboratory Objectives

The i-Hub living laboratories activity stream has the objective to quantify (i.e. analyse measurable data) and qualify (i.e. develop insights into reasons, motivations and opinions) the potential for practical and cost-effective innovative technologies in health care settings to achieve a 30%+ reduction in energy demand/consumption and greenhouse gas emissions relative to business-as-usual (BAU).

The aged care sector alone consumes approximately 8 gigajoules (GJ) of energy in Australia each year, with approximately 30% of this energy consumption in NSW alone. As Australia's population ages, the demand for aged care services is forecasted to increase in the coming years.

The provision of, or demand for, thermally comfortable environments through passive or active systems is a large driver for rising energy consumption in aged care facilities. HVAC presents a significant energy and demand challenge to aged care communities with social, technical, economic and environmental consequences.

Approaches to the provision of renewable energy in these facilities tends to happen in an ad-hoc and siloed approach, often without holistic consideration of the occupants, buildings, technologies and electricity grid, and the management and control of that system.

2. Challenges Experienced and How These Were Overcome

Despite best planning efforts, this living laboratory project experienced several challenges during the establishment and operation phase, not least being the challenges arising from a global pandemic including the restriction of personnel into aged care facilities. A selection of these challenges and the strategies implemented to overcome these are summarised below:

1. **Supply Chain Issues in Establishing Living Laboratory:** The Covid 19 pandemic shone a light on how interconnected the global supply chain is and sent ripples through many industries including the supply of monitoring and evaluation equipment resulting in increased procurement durations. The project had tight timeframes for establishing the living laboratory so that a nominal 12 months of baseline data could be collected followed by the trial of two technologies. Australian suppliers were sought for the majority of the required equipment with some equipment repurposed from other University of Wollongong projects.

2. **NSW Aged Care Restrictions:** Over the course of 2020 and 2021, Australia experienced numerous restrictions preventing the research team and potential technology providers from either travelling to or entering the aged care facility. Additionally, the research team took a risk averse approach with the researchers completing the project without entering the residential spaces of the aged care facility in order to best protect the residents. These restrictions introduced numerous technical challenges including how to setup a comprehensive indoor environment and quality monitoring system without entering the facility. To address this, the research team trained one the Building Services Officers (BSO's) to install the equipment and coached them via the phone to confirm accurate placement and readings. Additionally, all equipment that entered the facility was carefully sterilised and then placed in a quarantine space within the facility for a number of days before being installed.

   This also restricted the possible technology trials to include only interventions that were accessible without introducing risks to the residents. Fortunately, the distribution boards and HVAC condensers were both accessible without having to enter the residential spaces, enabling the researchers, technicians, and technology providers to access this equipment.

3. **Technology Readiness Level and Complexity:** A number of technology providers expressed interest and capability in the opportunity to demonstrate grid-interactive demand flexing HVAC control. However, it became evident when pressing for a detailed breakdown of the necessary components that need to be provided that no singular provider had all components at a sufficient technology readiness level for operation. Rather it is a partnership of providers that is required, coupling the demand response management with energy trading capability.

4. **Demand Response Capable Vs Demand Response Ready**: Despite the Warrigal HVAC systems being labelled as demand response enabled, this does not translate to a simple action of connecting them up and being demand response ready. Rather a third party (DNA Energy) was required to tap into this potential. DNA Energy produces an innovative module that interfaces with many existing commercial/industrial HVAC appliances that do not strictly comply with AS4755 but have Demand Response Enabled Device (DRED) equivalent functionality, thus enabling Demand Response Mechanism (DRM) response for very substantial portions of existing installed HVAC energy capacity that would otherwise be unable to participate. Additionally, granular energy meters are required to be installed to meet with the Frequency Control and Ancillary Services (FCAS) compliance requirements which can have its own on-site complexities. These challenges are resolvable when partnering with demand response specialists such as DNA Energy but may be challenging for building facilities managers attempting to navigate the complex demand market on their own.

3. Summary of Lessons Learnt and Evaluation of the Sub-Project Impact

The living laboratories project consisted of four major phases: establishment of the living lab, baseline data analysis, first technology trial, and second technology trial. A summary of the lessons leant and impact from each of these phases is presented below.

2.1. Establishing a Living Laboratory

Prior to determining the boundaries of the living laboratories, a Renewable Energy and Enabling Technology and Services Evaluation Framework (REETSEF) for the Healthcare Sector was first created which defined the KPIs and methods of evaluation to be used to assess the impact of technology upgrades. This REETSEF examined previous living laboratories and green proving grounds which highlighted that a range of societal, electricity network, and facility owner/manager KPI's were required to assess the effectiveness of potential technologies.

Following this, a virtual audit was performed on the facility with the assistance of the onsite BSO's and as built drawings. The REETSEF was then applied to produce a living laboratory operations manual which details the type and position of all installed sensors. This process also highlighted some of the potential areas for improvement such as demand response management of the HVAC systems. Links to these two reports can be found below.

Renewable Energy and Enabling Technology and Services Evaluation Framework (REETSEF)

Living Laboratory Operations Manual: Warrigal Residential Care Home

2.2. Baseline Data Analysis

An extensive building monitoring system was installed within the Shell Cove aged care facility consisting of Wattwatchers Auditor-6M metering-grade electrical energy monitoring, pulse output meters for gas consumption, and a combination of Nube iO Droplet DL-TH (temperature and humidity) and Elsys ERS CO2 (temperature, humidity, CO2, occupancy, and light level) sensors installed in most conditioned spaces within the living laboratories. These sensors communicate over either a LoRa wireless IoT network designed for very low power, long battery life with reasonably long range wireless transmission, or in the case of Wattwatchers via the 3G network. Additionally, a Davis Instruments wireless integrated sensor suite plus with fan-aspirated radiation shield (model number 6328AU) weather station and data logger was installed on the roof to the site to collect localised weather data.

Data collection commenced late August 2020 with the energy data supplemented with 2 years of utility billing data. This analysis revealed that HVAC accounted for 53% of the total electricity consumption for Level 2 (focus of living laboratory) with a split of 32% for the common areas, 21% for bedroom HVAC systems, and the remainder general power. Despite a large 99kWp solar PV array, the self-consumption remained high and approaching full utilisation due to the large electricity demand. This analysis also identified that there is approximately 258 kW of HVAC demand response capacity at the Warrigal Shell Cove facility, with 104 kW of this is associated with the living laboratory on Level 2 of the building.

The indoor environment and quality (IEQ) analysis between 28 August and 5 May demonstrated that the Shell Cove residential aged care facility maintains generally 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). Concentrations of CO_2 were also found to be below the threshold for concern most of the time. The analysis summarised 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. For more information regarding this baseline analysis, please follow the link below.

Warrigal Residential Car Home Monitoring and Baseline Data Analysis

2.3. Flow Power – Electricity Spot Price Trading

Flow Power is an innovative energy retailer, offering customers direct exposure to the wholesale electricity spot market. This technology evaluation considered Flow Power's pure pass-through wholesale product, in which customers are directly charged the wholesale spot price each 5-minute interval, plus a margin. The wholesale spot price is influenced by the amount of renewable generation in the grid (as well as aggregate demand), and on a typical day will have minimum prices during periods of highest generation.

The current evaluation identified that during most months of the evaluation period (14 of 19), the Warrigal site would have lower energy costs under the wholesale pass-through. However, in certain periods with more than the usual number of high price events, the Warrigal bill could be substantially larger than it would be under a traditional offering (up to 220% of the monthly energy cost). These high costs are typically caused by consumption during a small number of extremely high price events, where the wholesale price increased by several orders of magnitude. In the month with the highest estimated bill under the wholesale pass-through (Jan-20), 57% of the energy cost was caused by consumption during 5.5 hours with wholesale spot prices above $5,000/MWh, which is more than fifty times the average volume-weighted spot price in NSW of around $80/MWh. For comparison, the average fixed price for the existing supply contract was $104/MWh.

Analysis of the energy consumption and temperature profile in the Warrigal living lab during these high price events indicates substantial opportunity for HVAC demand response to reduce electricity costs in these periods. Greater detail of the evaluation can be found in the evaluation report, available by following the link below.

Flow Power Electricity Spot Price Trading Evaluation

2.4. DNA Energy – HVAC Demand Response

The National Electricity Market (NEM) operated by the Australian Electricity Market Operator (AEMO) is undergoing rapid transformation moving closer towards world-first levels of renewable generation. A key focus of AEMO is on managing an accelerating transition towards high instantaneous penetration of renewable generation, accelerating exit of coal, increasing electrification of heating and transport, and the introduction of 'green' hydrogen consumption. This increasingly dynamic balance of supply and demand in this marketplace is disrupting the conventional, relatively stable market with the increasing prevalence of negatively priced power during periods with high renewable generation.

AEMO manages a wholesale spot price market to balance supply and demand at 5-minute time intervals. Shorter-term fluctuations in supply-demand are managed and costed in the separate Frequency Control and Ancillary Services (FCAS) markets. FCAS 'Raise' markets trade capacity to raise frequency by increasing generation or shedding loads. 'Lower' markets trade capacity to lower grid frequency by decreasing generation or increasing loads. Through Demand Response Management (DRM) it is possible to better manage Demand Response Enable Devices (DRED) such as HVAC controls to reduce costs from wholesale market price spikes whilst also producing revenue by participating in the FCAS market.

DNA Energy is an innovative demand response technology provider, offering customers direct control of HVAC demand response technologies and other energy management solutions using cost efficient wireless devices. This evaluation examined the response times and practical demand response capacity of the Warrigal Shell Cove DRED for trading on the FCAS market and explored potential cost savings through predictively controlling HVAC demand flexibility.

The evaluation found that it was possible to actively control temperature setpoints within the facility to precool or preheat prior to an anticipated price spike event on the wholesale market. Additionally, DRM controls can be used to achieve faster demand response control to curtail HVAC loads for unexpected 5-minute price spike events. Furthermore, the thermal mass of the building provides adequate thermal stability to allow HVAC demand response control actions (both DRM controls and temperature set point flexing) to be sustained for multiple 5-minute trading intervals without any sudden or significant impact on indoor thermal comfort expected.

Typical peak spot price events were shown to be relatively brief and characterised by sharp rates of price rise above $300/MWh. Approximately 70% of spot price events that settled at greater than $500/MWh were only sustained for a single trading interval. Only three of these high spot price events were sustained for greater than 50 minutes during the period from October 2021 to May 2022. Together this demonstrates that considerable cost savings can be reached without significant changes to thermal comfort through the use of temperature set point flexing and DRM controls. Furthermore, the DNA Energy's DRM control enabling system in concert with the site's Mitsubishi Electric City Multi VRF condensers demonstrated the ability to participate in the FCAS Slow Raise, and potentially also the FCAS Fast Raise markets, although further work is required to resolve time response uncertainty errors in the monitoring equipment and Mitsubishi condenser controls. For greater detail please follow the link below to see the complete evaluation report.

Report will become available at: https://www.ihub.org.au/llhc2-warrigal-aged-care-establishment-and-operation/

2.5. Summary of Sub-Project Outcomes

Each sub-project was evaluated against a series of outcomes and KPIs. A summary of how the outcomes and KPI's associated with the Warrigal Aged Care i-Hub Living Laboratory sub-project have been achieved is provided below.

- *The establishment and operation of the Warrigal Aged Care i-Hub Living Laboratory:* Despite great challenges arising from Covid 19, the Warrigal Aged Care Living Laboratory was established. Monitoring of sub-meter energy consumption and IEQ have been recorded from August 2020 to June 2022. Warrigal has a long-lasting research relationship with the University of Wollongong and it is expected that the living laboratory continues to operate and invite future technology providers to evaluate their products or services within the facility.

- *Enable the Australian HVAC and building services industries to have their innovative technologies independently validated at the Warrigal Aged Care LL facility with at least 2 technology assessments of emerging products/services validated and published:* A prospectus inviting potential technology providers was produced and distributed to a broad network. This alongside of various industry presentations attracted a number of potential technology providers. As detailed above, two independent technology trials were conducted during the project with the evaluation reports published on the i-Hub website.

- *Practical and cost-effective ways that Aged Care Facilities will be able to achieve a 30%+ reduction in energy demand/consumption and greenhouse gas emissions, through the use of new technologies relating to HVAC control, demand management, grid interoperability and renewable energy are demonstrated:* The first technology trial evaluated direct exposure to the wholesale electricity spot market. Although by itself it does not reduce energy demand/consumption, this technology is observed to be an enabler of technology such as demand response where the consumer is able to seek larger economic benefits by reducing demand during peak events. This was explored in greater detail within the second technology trial where DNA Energy's DRM control system demonstrated the capacity for temperature set point flexing to pre-cool and pre-heat prior to forecasted high price events with DRED controls to quickly reduce energy consumption to avoid unexpected high price events and participate on the FCAS markets. The best indication of cost value that this study identified for FCAS was $69,000 potential value stream. This is contingent upon 6sec response time of condenser loads, however, necessarily aggregating these to 1MW trading increment at a multi-portfolio level is expected to manage this issue. The $69k would need to be shared with building owners likely to receive a minor portion, noting that FCAS markets are extremely volatile year to year and are very debatable as to their long-term prospects. However, this value stream exists for our evaluation period in the context of a site that has an annual electricity bill of $100k. While this reported savings is not energy reduction, creating demand response from existing HVAC loads, which are traditionally known as the major root cause of peak demand consumption events creates value for the grid with high renewables penetration.

4. CONCLUSIONS

The aged care sector consumes a significant amount of energy each year and this is expected to continue to increase as Australia's population ages. The i-Hub living laboratories activity stream sought to evaluate practical and cost-effective innovative technologies in aged care settings to achieve a 30%+ reduction in energy demand/consumption and greenhouse gas emissions relative to business-as-usual (BAU). The Warrigal Shell Cove Living Laboratory was established with an invitation sent to industry inviting them to have their innovative technologies independently evaluated in a real-life setting.

With Covid 19 placing considerable restrictions on the aged care sector, the scope of potential technologies was restricted to only technologies that could be implemented without entering the residential spaces of the facility, such as demand response control. The first evaluation focused on the potential benefits from Flow Power's power pricing package that exposes the facility to direct wholesale energy prices. This was observed to be an enabler of demand response with considerable energy cost savings possible through reducing HVAC demand during high price events. This was followed by the implementation of DNA Energy's innovative demand response wireless devices which enabled active demand response control of Warrigal's Mitsubishi Electric City Multi VRF condensers. The Warrigal Shell Cove facility was capable of having numerous demand response calls and temperature set point changes to reduce HVAC demands whilst having minimal impact to the internal environment. Coupled together, these technologies show great promise in reducing energy costs for the Shell Cove facility while reducing energy demand at peak grid times and enabling participation in the FCAS markets for stabilising grid frequency. The use of wireless devices also enables retrofitting to existing HVAC systems easier and more cost effective than other wired solutions.

The University of Wollongong has been conducting research in collaboration with Warrigal for numerous years, investigating thermal comfort, energy efficiency, and occupant wellbeing. It is anticipated that this relationship will continue into the future generating further benefits from the Living Laboratory with the option of future technology providers to evaluate their products or services within the facility.