The Innovation Hub

for Affordable Heating and Cooling

Lessons Learnt Report

Warrigal Residential Care Home Living Laboratory – Lessons Learned Report

Project – LLHC2

19 November 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.
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.

The information or advice contained in this document is intended for use only by persons who have had adequate technical training in the field to which the Report relates. The information or advice should be verified before it is put to use by any person. Reasonable efforts have been taken to ensure that the information or advice is accurate, reliable and accords with current standards as at the date of publication. To maximum extent permitted by law, the Australian Institute of Refrigeration, Air Conditioning and Heating Inc. (AIRAH), its officers, employees and agents:

a) disclaim all responsibility and all liability (including without limitation, liability in negligence) for all expenses, losses, damages and costs, whether direct, indirect, consequential or special you might incur as a result of the information in this publication being inaccurate or incomplete in any way, and for any reason; and

b) exclude any warranty, condition, guarantee, description or representation in relation to this publication, whether express or implied.

In all cases, the user should be able to establish the accuracy, currency and applicability of the information or advice in relation to any specific circumstances and must rely on his or her professional judgment at all times.

i-Hub Warrigal Residential Care Home Living Laboratory Lessons Learned Report

The i-Hub Warrigal Residential Care Home living laboratory establishes research-quality measurement and verification systems within 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.

This report explores the lessons learned from establishing this living laboratory and through evaluating technology upgrades. The lessons learned were developed through reflections and observations of the researchers and project team, and through interactions with the various project stakeholders.

Lead organisation	University of Wollongong		
Sub-Project number	LLHC2		
Sub-Project commencement date	1st July 2019	Completion date	30th June 2022
Report date	19 November 2021		
Contact name	Dr Georgios Kokogiannakis		
Position in organisation	Associate Professor at UOW's Sustainable Buildings Research Centre		
Phone	+61 2 4221 5795	Email	gkg@uow.edu.au

Important Note: The Warrigal Residential Care Home Living Laboratory was ran in parallel to the ACT Education Living Laboratory. Some of the lessons learned are applicable to both living laboratories. To improve readability (for those reading multiple living laboratory reports), any information included within the report which is similar to information outlined within other living laboratory reports will be highlighted with a greyed-out background.

Lessons learnt

Lesson learnt #1	Wholesale energy supply contracts can offer energy and cost savings but carry also risks without available HVAC demand response technology.
Category	Technical

Describe what you learnt about this aspect of the Project.

The Warrigal Residential Care Home was constructed in 2017 and has a series of heat recovery VRF (variable refrigerant flow) heat pump systems that service the buildings heating and cooling needs. The condenser units are demand response capable, with a total demand response capacity of 258 kW. The facility was found to have a stable temperature profile and coupled with a 99 kWp Solar PV system on the roof, demand response was seen as a great potential to meet the i-Hub objectives.

This opportunity was explored through detailed market research of technology providers with a focus on technologies that were at a deployment stage. Although a range of potential providers were found to have demand response solutions, no company was found to have a bespoke predictive HVAC demand flexibility solution that was applicable to the aged care sector. Rather the research team identified two separate companies where together they were capable of implementing demand response controls and trading the response on the energy market. Additionally, it was found that although Model Predictive Control (MPC) strategies exist, this type of advance control is still being developed for implementation in the aged care sector and it is not readily available for deployment.

It was found that the use of this energy supply contract provides an effective price signal by which to better coordinate HVAC usage with periods of lower wholesale prices, which are typically related to periods of high renewable generation (or lower aggregate demand).

Without the use of any active HVAC controls, the overall energy cost under the wholesale agreement would have been very similar to the cost of energy under the current supply contract from a tier 1 retailer for the living laboratory facility ($410 or 1% greater). However, there was substantial variation in the monthly energy cost under the wholesale agreement, from a maximum monthly cost of $20,201 (119% more than current bill) to a minimum of $3,130 (44% less than current bill). Further analysis revealed that the months with high energy costs were heavily influenced by a small number of high price events. These high price events typically occurred at short periods that would be conducive to various forms of energy flexing to reduce loads, and thereby significantly reduce energy costs.

Trading on the wholesale spot price market through this form of energy supply agreement appears to be a promising method to monetise HVAC demand response, by better aligning periods of HVAC consumption with periods of renewable generation and low spot prices. This solution is relatively simple in comparison with other methods of monetising demand response (i.e. FCAS, RTE and WDRM).

Please describe what you would do differently next time and how this would help. What are the implications for future Projects?

Exploring the impact of pre-cooling or pre-heating as HVAC demand response method using energy simulation tools prior to its application on-site. This would quantify the potential of demand response without being exposed to any thermal comfort related risks.

If your Project learnings have identified any knowledge gaps that need to be filled, please state it below.

1) Model predictive control of HVAC systems with advanced temperature set point flexing control interacting with the wholesale spot price market appears to be the state of the art for demand flexibility of HVAC

systems, however, this requires a research approach to bring these diverse technologies and services into an advanced industry-ready package.
Additional research and development is likely to be require to fully realise the potential of demand flexing of HVAC system based on wholesale spot price, as it requires bringing together diverse technologies and services to serve the needs of a specific sector.

2) Further investigation into the causes of high price events would be desirable but it is outside the scope of the study.

Please include any other information you feel is relevant or helpful in sharing the knowledge you learnt through this stage of the Project. This may be qualitative or quantitative and may include a graph, chart, infographic or table as appropriate.

This is explored in greater detail within the **Flow Power - iHub Technology Evaluation Report**.

Lesson learnt #2	Australian energy markets are complex.
Category	Technical

Describe what you learnt about this aspect of the Project.

The National Electricity Market (NEM) operated by the Australian Electricity Market Operator (AEMO) is undergoing transformation with increasing dependence upon renewable generation sources. Balancing generation supply and consumer demand in this dynamic marketplace is requiring significant adjustments to market mechanisms. Existing mechanisms to address these needs include:

- The Reliability and emergency Reserve Trader (RERT) for managing controlled shedding of major grid loads or to activate standby generation during extreme peak demand events
- The Wholesale demand response mechanism (WDRM) which differs from RERT in that it is integrated into the spot price market and does not depend upon AEMO to activate the opportunity. Consumers engage in the spot price market through the WDRM by submitting their demand response capacity and activation price threshold for each trading interval.
- Frequency Control and Ancillary Services (FCAS) which are operated to balance short-term generation and demand fluctuations that disturb grid frequency. The regulation FCAS markets are for major generators to modulate generation in response to minor grid frequency fluctuations. Whereas the contingency FCAS markets are more open to demand side customers as well as generators and are designed to manage sudden unexpected disturbance to grid frequency caused by the loss of a generation unit, a major industrial load or a large network transmission element.

The above traditional NEM demand response markets are traded in large units (typically 1 MW), which generally precludes individual HVAC systems. Virtual Power Plant operators are now providing a service to aggregate these demand response capacities for trading HVAC load flexibility on these demand response markets as an additional income stream in parallel to existing electricity supply agreements.

Further to these traditional demand response markets for major generators and loads, new trends are emerging where innovative electricity retailers are now offering a range of electricity agreement products that are designed to directly expose commercial and industrial consumers to the wholesale spot price signals to incentivise better alignment of loads to time-varying generation capacity. This is increasingly important as renewable generation proportion increases. HVAC demand flexibility has a advantage over other major flexibility assets, such as standby generators and battery systems, in that HVAC demand response systems require very little additional capital equipment to implement and can utilise existing building thermal mass for energy storage.

Consumers are provided direct access to the spot price settled for each trading interval, with a nominal fixed margin typically applied by the retailer. These wholesale electricity agreements could become major enablers for consumers with active demand flexing capability to effectively participate directly on the live spot price market without the forecasting and settling contractual constraints of the RERT and FCAS markets. However, with all these avenues, the NEM may appear daunting to building portfolio procurement managers, especially the demand response market opportunities with the NEM.

Please describe what you would do differently next time and how this would help. What are the implications for future Projects?
Negotiating this complex and unfamiliar NEM demand response market landscape required time to identify the best aligning opportunities for the HVAC industry for this particular sector. This time up front to map the stakeholders, issues and opportunities was an essential step in arriving at this valuable position, but this delayed the time between baseline data report and has limited the time to implement and evaluate the technologies. Establishing a collaborative engagement between AEMO experts, HVAC industry and researchers could have been a valuable catalyst for this process.

If your Project learnings have identified any knowledge gaps that need to be filled, please state it below.
The technology and enabling services required for implementing demand response, and the companies that offer these services, are often focussed on a specific sub-sector of the commercial building market (i.e. office spaces, or large chilled water systems). Each sector is likely to have a slightly different optimal technology and service mix through which to engage in demand response, and identifying this is currently challenging.

Please include any other information you feel is relevant or helpful in sharing the knowledge you learnt through this stage of the Project. This may be qualitative or quantitative and may include a graph, chart, infographic or table as appropriate.
This is explored in greater detail within the **Flow Power - iHub Technology Evaluation Report**.

Lesson learnt #3	Establish working relationships with Building Service Officers
Category	Social

Describe what you learnt about this aspect of the Project.

Establishing a living laboratory requires a series of site visits to gain a detailed understanding of how the building operates, gathering of plans, schematics and details the building fabric, installation and maintenance of monitoring sensors, etc. Under normal circumstances this is achievable with the primary barrier being the distance to the site. However, when faced with a global pandemic with restrictions on movements and access to sites, gathering this information becomes a considerable challenge. The research team was based in the Illawarra which was classed under Greater Sydney in terms of COVID-19 restrictions and additionally the living laboratory has immune compromised residents, thus restricting access to the living laboratory team for duration of the project.

This highlighted the critical importance of establishing good working relationships with the on the ground staff, especially the Building Services Officers (BSO's). Through collaboration with the BSO's, they were able to assist the

team in sourcing critical information about the building including plans, schematics, and materials. The BSO's assisted with the installation and maintenance of the installed monitoring system and conducted live virtual tours for potential technology providers and when troubleshooting issues. Establishing the living laboratories under the pandemic restrictions resulted in a significant increase in the workload of not only the research team but also the Warrigal staff which is provided through in-kind contributions.
Please describe what you would do differently next time and how this would help. What are the implications for future Projects?
The research team placed an emphasis on establishing relationships with the BSO's and building managers at an early stage of the project, however, it would be beneficial to include these critical stakeholders earlier in the process including at the concept formation stage. This would not only strengthen these relationships, but also enable the living laboratories to better focus on addressing exiting issues within the building.
If your Project learnings have identified any knowledge gaps that need to be filled, please state it below.
Something that is not widely considered is that optimum operation of HVAC system requires interactions from the designers and installers, but also the maintenance personal, operators, occupants of the building, etc. This is a complex array of stakeholders that require multiple consultations when conducting research or making changes to HVAC systems. In addition, in the aged care sector there are additional considerations around what is an appropriate internal environment for aged care residents, who controls HVAC, and for whose comfort. These factors are all highly important when considering changes to HVAC management and operation, especially using automated or semi-automated systems.
Please include any other information you feel is relevant or helpful in sharing the knowledge you learnt through this stage of the Project. This may be qualitative or quantitative and may include a graph, chart, infographic or table as appropriate.

Lesson learnt #4	Relevant stakeholders required for establishing a living laboratory are greater than expected.
Category	Social
Describe what you learnt about this aspect of the Project.	
Establishing a living laboratory requires a detailed understanding of the building and the installation of an extensive monitoring system to measure energy consumption and environmental conditions. However, the non-physical components are equally important, such as establishing legal contracts, understanding what energy contracts are in place, how energy bills are paid, who is the energy retailer, what is the operational schedule of the building, HVAC schedules, etc. All these non-physical elements of a living lab frame how the building is used and what is possible to achieve within the framework of the lab. The buildings also have their own history and have often undergone upgrades and retrofits over their lifetime. This brings an additional layer of complexities with missing information and plans with work sometimes completed by companies that no longer exist. Historical agreements or changing of ownership and contracts may also limit access to information such as energy data. All these also emphasise the importance of moving all possible	

information into digital records and potentially developing building models that will act as digital representations of the building stock.
Please describe what you would do differently next time and how this would help. What are the implications for future Projects?
In future projects it is recommended to build a stakeholder map early in the project or during the concept phase. This should examine how various workflows are undertaken. For example, how does the facility pay their energy bills? Who do they pay these to? Who is called when the HVAC isn't working or if someone is uncomfortable? How is new equipment acquired? Who is involved in renegotiating energy contracts and when is the next contract review? These are just a sample of activities and questions that should be asked and mapped to understand the critical personnel for gathering information, establishing and maintaining the living laboratories, and managing the installation, operation, and removal of technology trials. By completing this stakeholder map it will enable a clearer project scope to be defined and highlight potential issues such as missing information, earlier in the project.
If your Project learnings have identified any knowledge gaps that need to be filled, please state it below.
Please include any other information you feel is relevant or helpful in sharing the knowledge you learnt through this stage of the Project. This may be qualitative or quantitative and may include a graph, chart, infographic or table as appropriate.