Report #LLHC1-Final

Living Labs Healthcare Sector: Final Report (Knowledge Sharing Report)

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QUEENSLAND UNIVERSITY OF TECHNOLOGY

About i-Hub

The Innovation Hub for Affordable Heating and Cooling (i-Hub) is an initiative led by the Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH) in conjunction with CSIRO, Queensland University of Technology (QUT), the University of Melbourne and the University of Wollongong and supported by Australian Renewable Energy Agency (ARENA) to facilitate the heating, ventilation, air conditioning and refrigeration (HVAC&R) industry's transition to a low emissions future, stimulate jobs growth, and showcase HVAC&R innovation in buildings.

The objective of i-Hub is to support the broader HVAC&R industry with knowledge dissemination, skills-development and capacity-building. By facilitating a collaborative approach to innovation, i-Hub brings together leading universities, researchers, consultants, building owners and equipment manufacturers to create a connected research and development community in Australia.

This Project received funding from ARENA as part of ARENA's Advancing Renewables Program.
The views expressed herein are not necessarily the views of the Australian Government, and the Australian Government does not accept responsibility for any information or advice contained herein.

i-Hub Healthcare Living Laboratories Sector-wide engagement and impact

The Healthcare Living Laboratories Sector Engagement project quantified healthcare sector energy consumption, identified the potential for renewable energy technologies to reduce sector energy consumption and cost for HVAC in particular, and proposed requirements for optimal integration of renewable energy technologies.

Lead organisation
Queensland University of Technology (QUT)

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1 PROJECT OVERVIEW

1.1 Healthcare Sector Overview

In 2014-2015 Australia spent $161.6 billion on healthcare in 15 health care sectors (not including Aged Care) which contributed 7% of national CO2 emissions in that year. Hospitals accounted for 44% of these emissions. Energy use in this sector is also rising. The energy intensity of hospitals and aged care facilities is attributed to their 24/7 operation, the use of energy intensive equipment, and the need for infection and temperature control. There may also be onsite kitchen and laundry services.

The purpose of the Living Laboratory Healthcare Sector Wide project was to quantify healthcare sector energy consumption, identify the potential for renewable energy technologies to reduce sector energy consumption and cost for HVAC in particular, and propose requirements for optimal integration of renewable energy technologies. The HVAC, building services and healthcare sectors worked collaboratively to develop new key performance indicators and metrics that link energy performance to core health services, and to disseminate the knowledge from this project.

This project acted as the umbrella project for the four related living labs:

- LLHC2 (Warrigal Aged Care)
- LLHC3 (Fernhill Residential Aged Care)
- LLHC4 (Queensland Children's Hospital)
- LLHC5 (Net zero energy and resilient hospitals)

1.2 Project Operation

LLHC1 was jointly managed by Queensland University of Technology (QUT) and the University of Wollongong (UoW), with QUT taking a lead role.

A Healthcare Knowledge Sharing Taskgroup was established and met at key times to discuss project activities and provide feedback on project outputs. These meetings were held online (via ZOOM or MS Teams) and included the use of online collaboration tools (e.g. Padlet).

The main methods used in LLHC1 activities included:

- Desk top studies to establish baselines and living lab frameworks
- Desk top studies to examine potentially useful key performance indicators
- Collation of outputs from the living lab projects
- Participation in International Energy Agency Annex 80 (Resilient Cooling) and applying those activities to the living lab contexts
- Industry engagement (through the knowledge sharing taskgroup, AIRAH, and other organisations)

1.3 Project Outputs

This section summarises publicly available project outputs include project reports (Table 1-1), industry publications (Table 1-2), industry presentations (Table 1-3) and peer-reviewed scientific publications (Table 1-4).

Table 1-1 Project main reports

Report title	Brief synopsis
Healthcare Sector Energy Baseline	*Purpose:* to better understand current energy use, emissions and key performance indicators (KPIs). *Method:* (a) review of published national and international literature (government and sector reports, industry papers and academic publications); (b) evaluation of key performance indicators (KPIs) *Key findings:* (1) Energy use intensity (EUI) is the predominant way of reporting energy use. HCF EUI varies considerably, depending on the climate, the types of facilities, occupancy rates, equipment etc. Commonly used energy KPIs for EUI in hospitals are energy per floor area per annum, energy per bed day per annum, energy per bed per annum, or energy per separation per annum. In residential aged care, additional KPIs indicating EUI include energy per resident per annum, and heating (or cooling) energy per floor area per annum. (2) Existing KPIs (at building or equipment level) are inadequate for diagnosing challenges and opportunities for enabling renewable energy or energy storage, reducing or managing peak demand, or accounting for health and safety co-benefits.
Renewable Energy and Enabling Technology and Services Framework (REETSEF)	*Purpose*: to describe the general conditions that will be considered for the establishment and operation of the three healthcare living laboratories in order to meet the i-HUB objectives. *Content:* background to living labs; key performance indicators; measurement and verification; monitoring and metering requirements; data analysis methodologies; post occupancy evaluation protocols; contractual arrangements; ethics protocols; intellectual property protocols; technology selection process; technology reporting.
Healthcare Sector: Examination of the potential to align health and energy co-benefits	*Purpose*: to examine key performance indicators and metrics for indoor environment quality from the perspectives of health, building services, resilience and smart technologies *Method*: literature review *Outcomes*: highlights a vision of an integrated health and energy approach with the context of resource constraints, health-delivery models, climate change and resilience
Renewable Energy and Enabling Technology and Services Roadmap for Healthcare	*Purpose*: provide a practical guide to assist organisation to develop a bespoke renewable energy and enabling technologies and services implementation plan for individual healthcare buildings *Content:* the Roadmap consists of two parts: the establishment of a framework through which the plan will be implemented, and examination of the energy system options

Table 1-2 Industry publications

Title / link
Fok, Alan, Gregson, Scott, Groenhout, Nathan, Johnson, Greg, Lecamwasam, Lasath, Le Miere, Rene, et al. (2021) *The AIRAH Resilience Checklist.* The Australian Institute of Refrigeration, Air Conditioning and Heating (AIRAH).
"Integrated Design Studios for low energy aged care buildings. The cases of Wollongong, Melbourne and Queensland (Caboolture and Cairns)". *Australian Ageing Agenda*, Dec 2021

Table 1-3 Industry Presentations

Title	Type	Purpose
Artificial Intelligence in the Built Environment – Industry Forum (Aug, 2019)	Presentation and panel discussion	Engage QLD industry (AI in the built environment), re iHUB activities
Building Designers Association national conference (Aug, 2019)	Presentation and engagement with product providers	Engage building designers and product providers in discussion on iHUB Living Labs
Future of HVAC conference (Nov, 2019)	Presentation and engagement with product and service providers	Announce living labs to HVAC industry.
Power, Energy and Clean Technology Seminar (QUT) (Apr, 2021)	Web presentation on iHUB aged care energy performance and planning	Engage professionals, government employees, NGOS and academics in power and energy areas
iHUB Summit III (June 2021)	Webinar presentation on iHUB Living Labs	Engage professionals, industry participants, students and academics in HVAC&R areas
Webinar with Energy Queensland Demand Management Team (Sept 2021)	Presentation and discussion	Knowledge sharing; exploring potential areas for collaboration
Greening the Healthcare Sector Forum (Nov, 2021)	Presentation, panel discussion	Knowledge sharing; expanding networking opportunities with government, non-government, and clinical/health practitioner organisations
iHUB Outcomes Summit (May 2022)	Presentation, panel discussion	Summary of demand response findings for healthcare; industry discussion and feedback

Table 1-4 Scientific publications (journals and conference papers)

Title / link
Liu, Aaron, Miller, Wendy, Crompton, Glenn, & Ma, Yunlong (2020) Principles to Define Energy Key Performance Indicators for the Healthcare Sector. In *Proceedings of the 2020 International Conference on Smart Grids and Energy Systems (SGES).* Institute of Electrical and Electronics Engineers Inc., USA, pp. 898-903.
Liu, Aaron, Miller, Wendy, Chiou, James, Zedan, Sherif, Chen, Xi, & Susilawati, Connie (2021) How is occupancy related to energy use in healthcare buildings? In *Proceedings of the 2021 IEEE PES Innovative Smart Grid Technologies - Asia (ISGT Asia) Conference.* Institute of Electrical and Electronics Engineers Inc., USA, pp. 1-5.
Liu, Aaron, Miller, Wendy, Crompton, Glenn, & Zedan, Sherif (2021) Has COVID-19 lockdown impacted on aged care energy use and demand? *Energy and Buildings*, *235*, Article number: 110759.
Liu, Aaron, Miller, Wendy, Cholette, Michael, Ledwich, Gerard, Crompton, Glenn, & Li, Yong (2021) A multi-dimension clustering-based method for renewable energy investment planning. *Renewable Energy*, *172*, pp. 651-666.
Evans, Michael, Belusko, Martin, Taghipour, Alireza, Liu, Ming, Keane, Patrick F., Nihill, Jack, et al. (2021) *Electrification and Renewables to displace fossil fuel process heating: B3 Opportunity Assessment.* RACE 2030 (CRC for Renewable Affordable and Clean Energy), Australia.
Miller, Wendy, Machard, Anaïs, Bozonnet, Emmanuel, Yoon, Nari, Qi, Dahai, Zhang, Chen, et al. (2021) Conceptualising a resilient cooling system: A socio-technical approach. *City and Environment Interactions*, *11*, Article number: 100065.
Liu, Aaron, Miller, Wendy, Chiou, James, Zedan, Sherif, Yigitcanlar, Tan, & Ding, Yuemin (2021) Aged Care Energy Use and Peak Demand Change in the COVID-19 Year: Empirical Evidence from Australia. *Buildings*, *11*(12), Article number: 570.
Izadyar, Nima & Miller, Wendy (2022) Ventilation strategies and design impacts on indoor airborne transmission: A review. *Building and Environment*, *218*, Article number: 109158.

2 PROJECT ANALSIS AND EVALUATION

This section evaluates the project against its core deliverables, outcomes and KPIs (section 2.1), and analyses challenges (section 2.2), lessons learned (section 2.3), and impact (section 2.4). It concludes with a short discussion on 'what next' (section 2.5).

2.1 Deliverables, Outcomes and KPIs

The achievement of the knowledge deliverables, project outcomes and KPIs is reported in Tables 2-1, 2-2 and 2-3 respectively.

Table 2-1 Achievement of knowledge deliverables

Project Knowledge Deliverables	Evidence
Renewable Energy and Enabling Technology and Services Evaluation Framework for Healthcare (REETSEF)	*Renewable Energy and Enabling Technology and Services Evaluation Framework for Healthcare (REETSEF)* (Delivered in Milestone 3)
Sector wide energy performance data and key performance indicators	*Healthcare Sector Energy Baseline* (Delivered in Milestone 3)
Interim report: the role of indoor environmental control in the care plan for occupants and implications for energy demand and resilience	*Healthcare Sector: Examination of the potential to align health and energy co-benefits* (Delivered in Milestone 5)
Renewable Energy and Enabling Technology and Services Roadmap for Healthcare	*Renewable Energy and Enabling Technology and Services Roadmap for Healthcare* (Delivered in Milestone 7)

Table 2-2 Achievement of project outcomes

Project outcomes	Evidence
Quantification and qualification of the potential for integration of innovative heating, cooling and HVAC technologies and renewable energy in health care settings to help facilities transition to a net-zero energy/demand future while simultaneously contributing to occupant wellbeing, comfort and health	As reported in the Technical Evaluation Reports for LLHC2, 3 and 4 and the Technical Report (Future Energy Use) for LLHC4 As summarised in the final Knowledge Sharing Reports for LLHC2, 3, 4 and 5
A Renewable Energy and Enabling Technology and Services Evaluation Framework (REETSEF) that will be applied to Healthcare Living Lab operations and product validation protocols	REETSEF applied to three living laboratories: LLHC2 Warrigal Aged Care – Operation Guidelines LLHC3 Fernhill Residential Aged Care - Operation Guidelines LLHC4 Queensland Children's Hospital Operation Guidelines
Establishment of a Renewable Energy Knowledge Sharing Taskgroup for Healthcare that enables the two-way flow of information between the project and the sector	Terms of Reference developed. Taskgroup established. Taskgroup meetings (online); July '21; Dec '21; Apr'21; June'21

Baseline data that enables quantification of technology impact at a building level and extrapolation of sector wide impact	*Healthcare Sector Energy Baseline* (Delivered in Milestone 3)
Enhanced industry understanding of links between energy and health; and improving the value proposition for energy efficiency / renewable energy	*Healthcare Sector: Examination of the potential to align health and energy co-benefits* (Delivered in Milestone 5) *Renewable Energy and Enabling Technology and Services Roadmap for Healthcare* (Delivered in Milestone 7)
Demonstration of potential for a 25% increase in the value of renewable energy for hospitals and aged care facilities, relative to existing baseline metrics	The impact of technologies on renewable energy value has been reported in the Technical Evaluation Reports (LLHC2,3 and 4); the LLHC4 Technical Report (Future energy use). LLHC5 (Net zero energy and resilient hospitals) demonstrates the impact of future climate on energy demand and renewable energy potential. IDS13 and 14 demonstrated the increase in the share of renewable energy (in meeting energy loads) in response to passive design and HVAC technology selection. The LLHC1 Roadmap brings these findings together, demonstrating the value of an integrated approach (demand reduction through improved building envelope; HVAC technology selection and operation; DR participation and renewable energy applications) in helping healthcare facilities achieve net zero carbon emissions goals.
Demonstration of potential for a 30%+ reduction in energy demand/consumption and greenhouse gas emissions, relative to existing baseline metrics	Technology Evaluation Reports (LLHC2, 3 and 4) and the Technical Report (LLHC4) indicate energy consumption savings over 30% (through better HVAC management and/or heat load management) and demand savings greater than 10%. The options and feasibility for demand response participation have been evaluated (LLHC5) and included in the Roadmap (LLHC1).
A Renewable Energy and Enabling Technology and Services Roadmap for Healthcare that can be utilised by healthcare sector in their policy and procedure processes and decisions regarding energy contracts, building design and operation, and renewable energy investments	*Renewable Energy and Enabling Technology and Services Roadmap for Healthcare* (Delivered in Milestone 7) Once approved, will be distributed to the HVAC&R industry (through AIRAH) and the health industry (through the AHIA, Doctors for the Environment Australia (DEA), Climate and Health Alliance (CAHA), and private hospital and aged care providers.

Table 2-3 Achievement of key performance indicators

Key Performance Indicators (KPIs)	Evidence
Establishment of a Renewable Energy Knowledge Sharing Task Group for Healthcare, and the level of industry engagement in the process	Terms of Reference developed. Taskgroup established. Taskgroup meetings (online); July '21; Dec '21; Apr'21; June'21
Approval of REETSEF for Healthcare Living Labs	*Renewable Energy and Enabling Technology and Services Evaluation Framework for Healthcare (REETSEF)* (Delivered in Milestone 3)
Sector baseline data distributed to stakeholders	*Healthcare Sector Energy Baseline* (Delivered in Milestone 3) and distributed through iHUB website and through QUT and UOW to key stakeholders
Utilisation of the REETSEF in the establishment of the Healthcare Living Labs	Applied to LLHC2, 3 and 4 (incorporated into their Operations Manual)
Interim report distributed to sector	*Healthcare Sector: Examination of the potential to align health and energy co-benefits* (Delivered in Milestone 5) Distributed through iHUB website and through the Knowledge Sharing Taskgroup.
Roadmap produced includes analysis of the potential for increased value of renewable energy and reduction in energy demand / consumption, against baseline metrics	*Renewable Energy and Enabling Technology and Services Roadmap for Healthcare* (Delivered in Milestone 7)
Roadmap distributed to industry / professional organisations	Once approved, the Roadmap will be distributed through iHUB website and directly to the following organisations: • NABERS • AHIA (state government public health depts.) • Private hospitals (Mater Group, Uniting Care) • Aged care providers (Carinity, Anglicare, Bolton Clark) • Doctor for the Environment Australia (DEA) • Australian Medical Association (AMA) • Various medical colleges

2.2 Challenges

No significant challenges were experienced (other than those related to COVID-19).

2.3 Project Impact

The main project impact has been in the expansion of the i-HUB 'sphere of influence' in three significant areas:

(i) Engagement with NABERS (through NABERS for Residential Aged Care and Retirement Living; NABERS for Hospitals; NABERS Accelerating Net Zero Buildings)

(ii) Engagement with the Australasian Health Infrastructure Alliance (AHIA) and the subsequent co-funding of LLHC5 to explore net zero energy and resilient hospitals

(iii) Engagement with the clinical side of healthcare through the Climate and Health Alliance (CAHA) and Doctors for the Environment Australia (DEA) and the inclusion of their perspectives and reports in the development of the Roadmap.

2.4 What comes next

2.4.1 A formal national collaboration vehicle

The networking that has been developed through LLHC1 is significant, and it would be beneficial to find ways of continuing. We support the recommendations of the DEA and Australian Medical Association (AMA) for the establishment of a national Sustainable Healthcare Unit (SHU) as an appropriate vehicle for this collaboration. The SHU would conceivable incorporate clinical perspectives (DEA, AMA and medical colleges); hospital asset management perspectives (AHIA and private hospitals); aged care providers and/or overarching bodies; the air conditioning industry (AIRAH), the renewable energy industry (e.g. Clean Energy Council); NABERS; the Energy Efficiency Council (IEE) and academia.

It could potentially be co-funded through the Department of Industry Science Energy and Resources (DISER), ARENA, AHIA and others.

2.4.2 Recommendations for further work

Some areas for further work have been identified, as summarised in Table 2-4.

Table 2-4 Further work

Broad category	Need
Building Models	Development / Approval of hospital and aged care 'model' buildings for use for NCC code development and design development by stakeholders (for optimising building envelope, and for selection and sizing of HVAC systems and renewable energy systems).
Climate files	Comprehensive comparison of different future TMY climate files available, in terms of their respective usefulness for health facility modelling and HVAC and PV system sizing. Development of 'extreme weather' files for Australian contexts, perhaps based on the methodology developed through IEA Annex 80.
Electrification of heat loads	A decision-making framework and guidelines for heat pump technologies, in the move for electrification of heat loads
Demand response	A deeper investigation of energy assets in healthcare facilities that could be utilised for DR (for load shifting, load curtailment). A guideline for DR participation by healthcare facilities.
HVAC&R	A procurement guideline for HVAC in aged care facilities.
Next-gen BMS	A decision-making framework and/or guideline relating to the use of Digital Twins and Artificial Intelligence in predictive maintenance, demand response and predictive control.
Data Platform	Investigation of the value of the Data Clearing House platform and associated apps, to enable better benchmarking and energy optimisation in healthcare facilities.
Ventilation Effectiveness	Further investigation of the decay rate of airborne particles in HVAC systems; and the effectiveness of alternative ventilation strategies. (LLHC 5 and LLHC4 – Technical Report highlight the energy impact of current pandemic mode ventilation strategies and raise questions about the effectiveness of these strategies on containing contamination spread in healthcare facilities.)