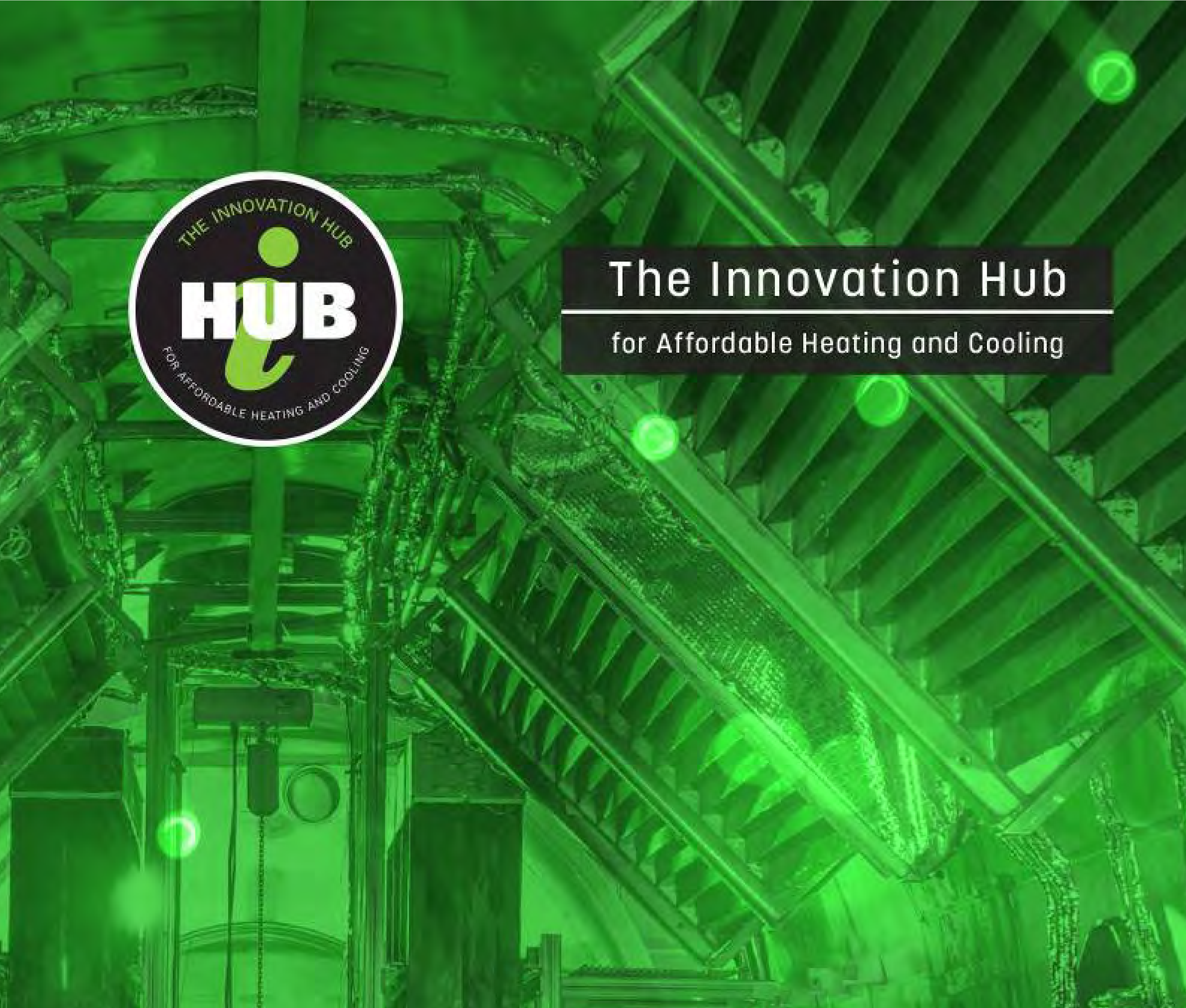

The Innovation Hub

for Affordable Heating and Cooling

Report #LLHC5-Final

LLHC5 Net Zero Energy and Resilient Hospitals: Knowledge Sharing Report

31 May 2022_V1

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.
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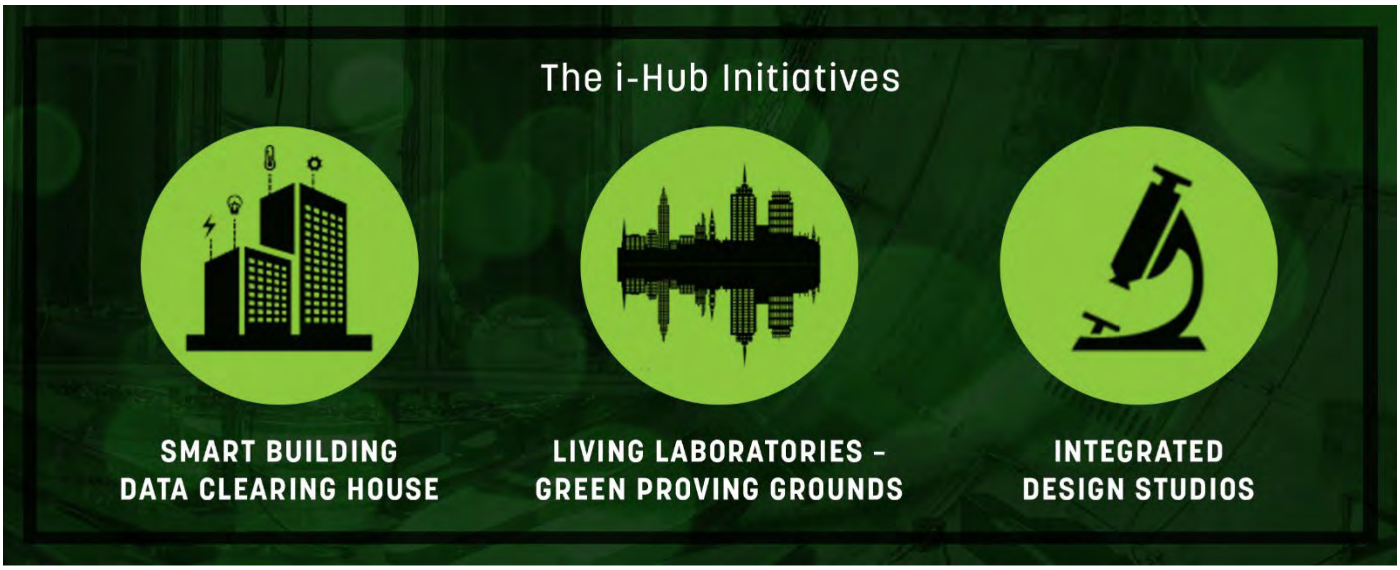

Healthcare Living Laboratories: Net Zero Energy Hospitals – Final Report

Energy is essential to ensure safe and reliable healthcare delivery. As detailed in our previous reports, the healthcare industry uses a lot of energy due to the nature of its operation and healthcare needs. This energy use has impacts on both environmental and financial sustainability. Public hospitals can be the largest single emitter and energy user in Australia's public service portfolio, as well as representing the largest single budget portion. For example, over 30% of Queensland's state budget is typically assigned to public hospitals.

The purpose of this project is to assist healthcare facility asset managers in operating and managing their building and energy infrastructure assets. The project focuses on future proofing facilities through (i) simulating the impact of future climates on thermal demand, HVAC performance and renewable energy potential; (ii) evaluating the impact of HVAC operation in response to COVID-19 management; (iii) assessing the feasibility of hospital participation in demand response markets. Project outputs will be a set of guidelines or processes to supplement the Australasian Health Facilities Guidelines for the benefit of both public and private health facilities.

Lead organisation
Queensland University of Technology (QUT)

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1 NET ZERO ENERGY AND RESILIENT HOSPITALS

This project addressed four gaps that were identified in literature and in previous i-HUB Healthcare Living Lab activities. The main findings of these activities are highlighted here.

1.1 Hospitals' Future Energy Use into 2030 – 2090

Two hospital models, based on real hospitals, were developed to enable simulation of the impact of future climates on the energy use of hospitals around Australia. The small hospital model is single storey with a floor area of 8203m2; the large hospital has 6 storeys and a floor area of 142,789m2. Both models were simulated for the current climate and four future climates (2030,2050, 2070, 2090) in 10 locations around Australia. Key findings as shown in Figure 1-1 and Figure 1-2:

- All locations, except Canberra and Hobart, will have increased levels of HVAC energy use.
- Northern Australia may be more negatively impacted in terms of using more energy and having a faster rate of change in HVAC energy use. This may indicate a need to consider now a longer planning horizon than other regions.
- Heating needs significant amounts of energy for most sites. For example, 2 to 6GWh of yearly heating energy needs for the large hospital model in most locations and future scenarios. Ground source heat pumps can reduce at least 70% of the heating electricity needs and at least 16% of total site electricity needs in Adelaide and Melbourne climates considering current and future climate scenarios.

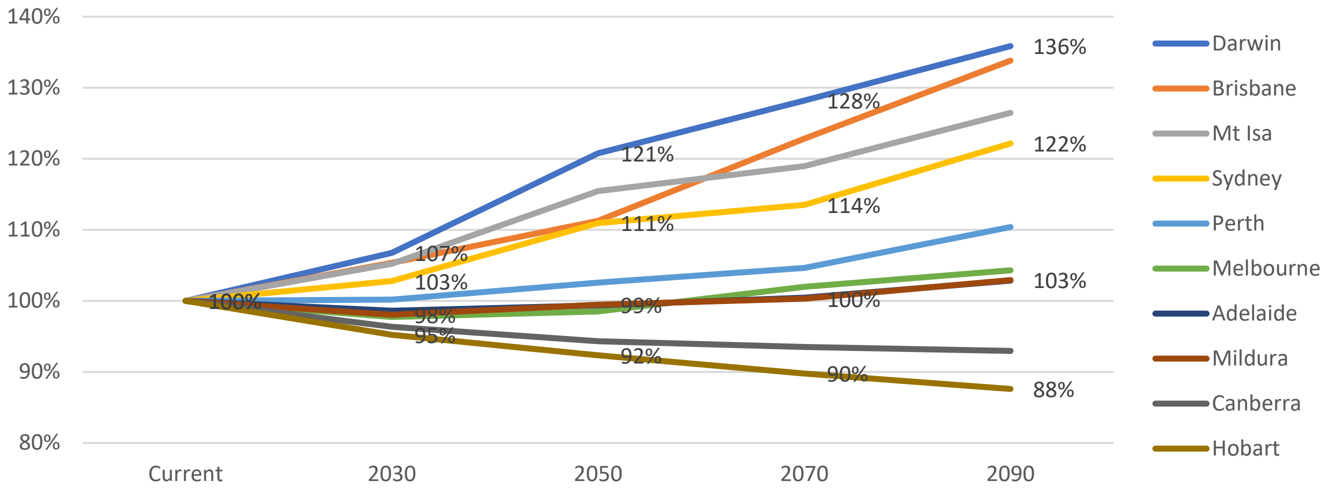

Figure 1-1 Small hospital HVAC energy use yearly benchmarking

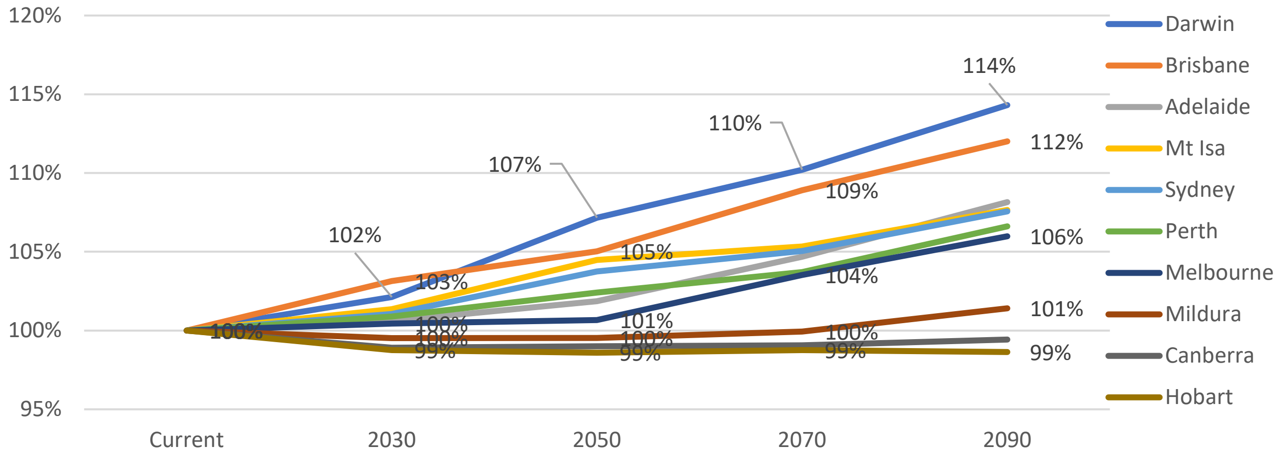

Figure 1-2 Large hospital HVAC energy use yearly benchmarking

Recommendations for future work are:

1. Development of typical hospital and aged care building models for NCC development.
2. Development of a decision-making framework and guidelines for heat pump technologies (in the move for heat electrification in hospitals)
3. A comprehensive comparison of the different future climate files available, in terms of their respective usefulness for hospital modelling and HVAC and PV system sizing
4. Development of 'extreme weather files' for Australian contexts, perhaps based on the methodology developed by the International Energy Agency (IEA) Annex 80 Resilient Cooling.

1.2 Pandemic Mode HVAC Operation

A hospital ward energy and thermal model was developed using Integrated Environmental Solutions – Virtual Environment (IES-VE) v2019 modelling package. The model was simulated for three scenarios (Table 1-1).

Table 1-1 Pandemic mode HVAC operation simulation scenarios

No	Description	Impact
1	Base Design (Scenario 1)	Parameters as documented within this Section
2	Scenario 2a	Base Design changed to 100% outdoor air with G4 & F8 Filters
3	Scenario 2b	As per Scenario 2b with F8 filters changed to F9

The simulations showed that the impact on annual energy use (normalised kWh/m2) for Melbourne was relatively small (11-13%), whilst in Darwin the impact was more substantial (120-124%). Peak thermal loads also increased.

Future work could include applying the same model and scenarios to other climate zones; and using the same model to simulate the impacts of other HVAC operation strategies. Note that the effectiveness of some HVAC operation strategies is explored in another i-HUB report; LLHC4 Technical Report: Future Energy Use.

1.3 Impact of future climate on renewable energy potential

The results from the hospital modelling into the future were used to determine the renewable energy impact of increases in HVAC energy use. Hobart and Canberra were excluded from the analysis as both are projected to have decreased HVAC energy use by 2090, and both jurisdictions already have 100% renewable energy electricity supply (or are likely to have in the near future).

For the small hospital model: over 100kWp of PV will be needed to offset the increased HVAC energy for Darwin and Brisbane climates in the 2090 scenario. Melbourne, Adelaide and Mildura will need over 20kWp new PV to offset increased HVAC energy use for the small hospital in the last two decades of this century.

For the large hospital model: 300 ~ 400kWp of PV will be needed to offset the increased HVAC energy for Darwin and Brisbane climates in the 2090 scenario. Mt Isa, Sydney, Perth and Melbourne will need over 200kWp new PV for the large hospital to offset HVAC energy use increase in the last two decades of this century. Adelaide will need over 300kWp new PV and Mildura will need 137kWp new PV in the 2090 scenario.

1.4 Demand Management and Market Participation

Demand response market participation options were examined, and key risks, benefits and challenges were identified. A case study analysis used data from a major Australian hospital. Key findings include:

- There are three main pathways to participation in demand response, ranging from simple to complex.
- To complete a DR participation assessment requires the collation of site-specific information, modelling software and the targeted DR markets for participation.
- The four broad barriers relate to network connection requirements, AEMO registration, infrastructure upgrades and minimum generator size.
- The case study analysis (5 year period) showed that, for this hospital in this network:
  - participating in the NEM spot high price event and FCAS contingency raise markets presents significant DR opportunities, whereas targeting network charges did not (for the assumed network tariff).
  - the majority of DR revenue relies on extreme events on the NEM, and the quantity and scale of these events vary each year. This means future revenue forecasts are not guaranteed.
- Eight risks or considerations were identified, each with proposed mitigation strategies.
- Future work could include
  - A deeper investigation of energy assets that could be utilised for DR
  - A guideline for DR participation by healthcare facilities (this report is a good base)

2 PROJECT ANALYSIS AND EVALUATION

This section evaluates the project against its core deliverables, outcomes and KPIs (section 3.1), and analyses challenges (section 3.2), lessons learned (section 3.3), and impact (section 3.4). It concludes with a short discussion on 'what next' (section 3.5).

2.1 Deliverables, outcomes and KPIs

The six specific project knowledge deliverables, and how they have been met, are shown in Table 3-1. Achievement of project outcomes is shown in Table 3-2, and project KPIs in Table 3-3.

Table 3-1 Achievement of knowledge deliverables

Project Knowledge Deliverables	Evidence
Short Summary	Delivered March 2022
RMP	Delivered March 2022
PR11 Report	Delivered May 2022
Lessons Learned	Delivered May 2022
M7 Report	Delivered May 2022
Supplementary guides to Australasian HFDGs	LLHC5 Project Report, delivered May 2022
Digital twin models used for the analysis	2 building models available to the AHIA for future use
Final knowledge sharing report	This report

Table 3-2 Achievement of project outcomes

Project outcomes	Evidence
Quantification of building thermal demand and HVAC energy use and peak demand in future climate scenarios	Section 3 of Project Report
Quantification of kW and kWh impacts due to changes of HVAC settings to manage COVID risk	Section 4 of Project Report
Evaluation of renewable energy kW required to meet any quantified increase	Section 5 of Project Report
Assessment of DR market participation feasibility for hospital facilities	Section 6 of Project Report

Table 3-3 Achievement of key performance indicators

Key Performance Indicators (KPIs)	Evidence
Number of hospital building models	Two hospital models developed (1 small, 1 large)
Number of future climate scenarios simulated	116 simulations: Two buildings * 5 climates (current TMY + 2030, 2050, 2070, 2090) * 10 climate zones (8 capital cities + Mt Isa + Mildura) One building * 2 locations * 5 climate scenarios One building * 2EFMY climates (2030, 2050)
Number of HVAC cscenarios simulated	Electric boilers and water source heat pumps simulated (electric boilers for both buildings for 5 climate scenarios and locations; water source heat pumps for large building for 2 locations for 5 climate scenarios)
kW and kWh impacts identified	
DR capacity identified	Section 6 of Project Report
1 final report	Project Report
1 knowledge sharing event	Three workshops held with stakeholders One seminar (i-HUB Outcomes Summit, Sydney May 2022)

2.2 Challenges

The main challenge of this project was the extremely short time frame (4 months from initiation to final reporting).

2.3 Lessons Learned

The key lesson learned is that there is no national collaboration vehicle for the healthcare sector that enables and supports public and private health providers to work together to overcome common challenges and achieve common goals (net zero emissions).

2.4 Project Impact

The outputs of this project have been shared with AHIA and other stakeholders. The respective organisations will decide to what extent the material in this project report, and other i-HUB healthcare reports, can be incorporated into their processes and practices.

The two building models are available to AHIA members for utilisation.

The project team will liaise with the AHIA regarding the potential for these two models to be

- Used by the Australian Building Codes Board for regulation assessment for the National Construction Code
- Used by IEA Annex 80 for modelling different resilient cooling technologies for a range of climate zones within Australia and internationally.

2.5 What comes next

(This section is the same as per the LLHC1 Knowledge Sharing Report)

2.5.1 A formal national collaboration vehicle

The networking that has been developed through Living Lab Healthcare activities 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.

2.5.2 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.)