The Innovation Hub

for Affordable Heating and Cooling

Report #IDS14-Knowledge Sharing Report

IDS14 – Tropical and Sub-tropical Mixed Use Buildings

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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.
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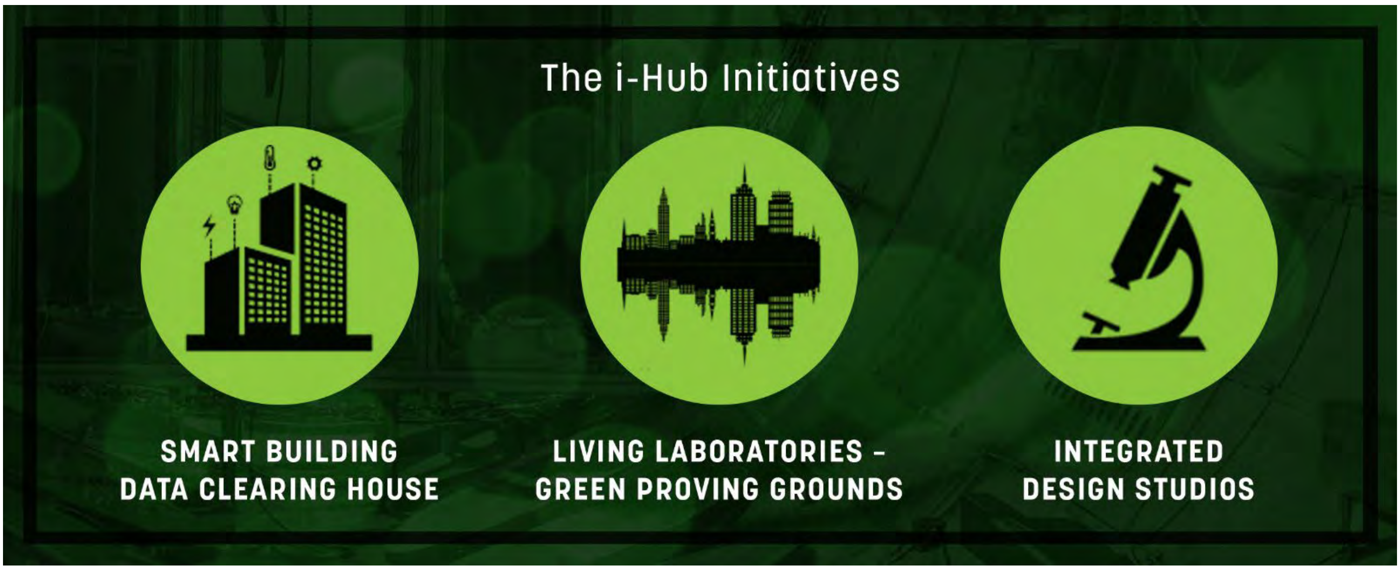

Healthcare Living Laboratories: Net Zero Energy Hospitals – Final Report

The Tropical Mixed-Use Building Integrated Design Studio (IDS 14), and the subtropical studio (IDS13) investigate design innovation in a mixed-use building typology that incorporates aged care. The climatic contexts are tropical Cairns and subtropical Caboolture (Queensland). The objective is to reduce net energy consumption through passive and active measures (e.g. the use of renewables and other energy technologies), whilst at the same time addressing the needs of different building occupants (including the elderly) and the whole-of-life focus of the client (Bolton Clarke). Over a period of 2 semesters (March – November 2021), a group of architecture and non-architecture students (mechanical/electrical engineering and construction management) worked with architecture, engineering and sustainability experts and the client to develop design solutions for this context. Innovations were then vetted by consultants.

High energy use in aged care facilities is attributed to their 24/7 operation, with a considerable portion of energy use attributed to space heating and/or cooling. The tropical climate of Cairns presents challenges in the design of buildings (passive design and materials selection); in the selection, design and operation of heating and cooling technologies; and in the utilisation of renewable energy and associated technologies to manage peak demand and greenhouse gas emissions.

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Contact name
Associate Professor Wendy Miller

Authors
Associate Professor Wendy Miller

Email
W2.miller@qut.edu.au

Project website
www.ihub.org.au

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1 IDS 13 AND 14

IDS 13 and 14 were run concurrently, with the same client and industry consultants. Each studio produced a Studio Report that summarised the key design features unique to each climatic context, as well as the process and implementation learnings (the same for both studios).

As the client for both contexts was a vertically integrated company that develops, owns and operates aged care facilities, designs requirements included consideration of whole-of-life (WOL) aspects and total-cost-of-ownership (TCOO) as well as net zero energy (NZE) and net zero carbon (NZC) considerations (encompassing the concepts of passive design to minimise space heating and cooling loads, selection of efficient and controllable space heating and cooling technologies, and the application of onsite renewable energy generation).

One key finding is presented below.

1.1 Mixed Use Buildings

Mixed-use building typologies present a number of challenges for achieving net zero energy, such as:

- There is no 'business as usual' (BAU) energy use intensity (EUI) data for this building typology. BAU estimation requires obtaining average EUI data for each of the building classes expected to be incorporated into the mixed-use building.
- Spaces within a mixed-use building can be used for different purposes (and by different classes of buildings) over time, so measurement of energy performance against BAU becomes even more problematic.
- There is no clear methodology for allocating energy consumption and generation data (whole and parts) for a mixed-use building, making it difficult to assign energy consumption costs, renewable energy generation benefits and demand response capabilities (who pays, who benefits, who decides?). It also presents challenges for the setting (and meeting) of net zero carbon or net zero energy goals (e.g. does it relate to all tenancies, or just common areas? Who decides on the target?)
- Mixed-use buildings that incorporate residential services present a unique problem in that the building is both a home and a workplace, creating additional challenges relating to HVAC technology selection, system sizing, design and operation.

2 PROJECT ANALYSIS AND EVALUATION

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

2.1 Deliverables, outcomes and KPIs

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

Table 2-1 Achievement of knowledge deliverables

Project Knowledge Deliverables	Evidence
Lessons Learned Report	IDS14 Lessons Learned Report
Milestone Report	IDS14 M7 Report
IDS 13 Final Studio Report	IDS 13 Final Studio Report
IDS 14 Final Studio Report	IDS 14 Final Studio Report
IDS Webinar	i-HUB Outcomes Seminar, May 2022, Sydney
Academic Paper	IDS Activity Stream have delivered 3 papers
Industry Article	Article in the Ageing Agenda, Dec 2021 Edition
Knowledge Sharing Report	IDS14 Knowledge Sharing Report (this report)

Table 2-2 Achievement of project outcomes

Project outcomes	Evidence
Overcome discipline prioritisation and risk-management barriers that prevent design consultants from providing innovative designs for their clients that include energy optimisation and renewable energy integration while also considering constructability, operational ease and asset life.	Identification of procurement contract that would support integrated design Development of Integrated Design Principles for Net Zero Energy Buildings (refer to IDS 13 and 14 Studio Reports for more details)
Contribute to the knowledge and development of the IDS process.	Identification of five key factors as being important to successful outcomes Development of Integrated Design Principles for Net Zero Energy Buildings
Potential contribution of innovations that (i) increase the fraction of building energy that can be economically provided by on-site renewable energy (target 25% increase relative to business as usual) and (ii) maximise local use of on-site renewable energy (e.g. through demand shifting/management/control/storage options)	Findings in IDs 13 and 14 Studio Reports. Key highlights: IDS 13 identified 20-44% reduction in cooling load, leading to a higher % of renewables meeting the load; + additional co-benefits in health and environment. IDS 14 identified 16-30% reduction in cooling demand; 21% reduction in peak cooing load; 80% reduction in operational and maintenance costs (HVAC); 2-8% increase in PV output; 12-100% ratio of PV meeting site load; 100% potential for PV-Hydrogen solution at a precinct level

Table 3-3 Achievement of key performance indicators

Key Performance Indicators (KPIs)	Evidence
Each IDS (13 and 14) produces 4-6 innovative design concepts	21 design concepts produced. Refer to IDS 13 Studio Report and IDS 14 Studio report for highlighted designs
Technical vetting by non-architecture students and consultant team presents quantifiable comparisons showing performance relative to BAU.	Vetting carried out on a number (10) of selected design concepts. Refer to IDS 13 Studio Report and IDS 14 Studio report for highlighted designs
Solutions presented that consider on-site renewable energy as an integral component of high efficiency/net zero building design, with consideration of integration for revenue/performance/asset value optimisation rather than an add-on (minimum one solar integrated design concept per studio)	All solutions considered renewable energy as an integral part of the solution, starting with addressing passive solutions to the building envelope, to reduce cooling demand. Some design concepts demonstrated that dramatic reduction in cooling demand (through building envelope improvements) opens up avenues for cooling technologies that are otherwise technically not feasible (e.g. radiant cooling). Building envelope thermal efficiency (and hence cooling load reductions) also impacts on the % of demand able to be met by renewables. Design concepts included upto 100% renewable contribution. Refer to IDS 13 Studio Report and IDS 14 Studio report for highlighted designs
Information from the IDS studio process shared with the wider industry (e.g. through webinar/workshop, design showcase, articles for industry publications and academic publications)	Participation in i-HUB summits, including Outcomes Summit. Participation in UniMelb IDS Lunchtime Symposia 25-27 Oct, 2021

2.2 Challenges

There were no main challenges to the operation of the studios per se. There were some challenges in the application of integrated design, as a process. These challenges relate to

- Understanding the various roles, responsibility, terminoloty and processes of different disciplines
- Developing rapport, trust and mutal respect as codesigners
- Applying a whole-of-life systems thinking mindset to design ideation
- Low technical skills from emerging designers (inexperience).

2.3 Lessons Learned

The key lessons learned, as discussed in more detail in the IDS 14 Lessons Learned Report, include:

- Co-design is a terminology the needs clarification
- Integrated design thinking is difficult for all participants at the earl stage where no building form is yet determined
- Procurement methods can inhibit or support integrated design
- Mixed-use buildings present design challenges
- A set of design principles could be beneficial.

2.4 Application to Industry

Five key factors, interrelated and interdependent, were identified as being important to successful outcomes from an integrated design process:

- A client brief that is open to being developed through the integrated design (ID) process, rather than pre-established
- A recognition of all participants, irrespective of profession, being equal co-designers, and a new or specialist role of integrated design facilitator or systems integrator.
- An early process whereby all participants gain an understanding and appreciation of each profession's language and design processes
- A range of communication strategies to capture different skills and methods used by the team
- A whole-system thinking approach that, from an energy perspective, considers the building, its services and technologies, and the energy systems that power it; as well as the human systems that inhabit the building and the climate in which the building and humans exist. It reaches beyond energy performance outcomes, but looks for multiple benefits from single solutions

The implementation of integrated design will require a suitable procurement instrument. The ID process is not well served by traditional procurement contracts (e.g. design and construct D&C), or even collaborative procurement contracts such as early contractor involvement (ECI). Integrated Project Delivery contracts appear more suitable, as they establish individual and group accountability. All parties accept, manage and share design and construction risks. Financial risks and rewards are shared through an agreed profit/incentive pool based on quantifiable project outcomes. An Alliance Contract is one such IPD contract type. An alternative contract type, suitable for integrated whole-life delivery projects, may be a Design-Build-Operate (DBO) contract. Refer to Table 4-1 for more information.

A proposed set of IDP Design Principles for NZE has been developed, based on Rocky Mountain Institute's Factor 10 Engineering Design Principles. This set of principles is proposed as a starting point for companies wishing to engage in integrated design. Refer to Section 4.2.2 for more information.

Table 1-4 Integrated Design Principles for Net-Zero Energy Buildings

Design phase	Integrated Design Principles for Net-Zero Energy Buildings
Before design starts	Establish a clear, shared, ambitious NZE goal and timeframe for achieving that goal. Consider including other related goals, such as resilience, adaptation, grid autonomy. Determine KPIs that reflect the goals, including ambitious energy efficiency.
	Convene a transdisciplinary design team (e.g. engineers, architects, construction contractor, building owner/manager/occupants, ID specialist/facilitator) with diverse skills and experiences.
	Avoid the linear march through traditional design phases (project objectives and aspirations; design concept development; master planning; design development; feasibility evaluation). ID is iterative, with successive stages informing earlier ideas.
	Implement an Integrated Project Delivery contract that rewards teams for meeting KPIs and providing savings, rather than producing documents.
Focus on the right problem	Understand the purpose of the building and the needs of the people who will occupy it. What energy services will be required and what environmental, regulatory, technical and social contexts are likely to exist over this period?
	Push past end-uses (e.g. HVAC), resulting services (e.g. comfort) and ultimate benefits (e.g. health, productivity) to understand the full range of ways to fulfill the purpose/s.
	Take a whole-of-life approach to designs and their consequences (i.e consider current and future occupants and environmental context).

	Establish BAU benchmarks for the KPIs, and whole-system, lifecycle value of savings (e.g. in kWh, kW, CO2e, HVAC kVa, PV kWp etc)
	Use science and the plethora of simulation and modelling tools available to determine the theoretical minimum amount of energy needed to provide the energy services (especially HVAC). Consider how far each practical design constraint (e.g. cost, safety, performance, accessibility) moves away from that theoretical minimum.
Design Integratively	Don’t start with a familiar or previous design or conventional assumptions or methods. Start afresh with no preconceptions.
	Question all rules of thumb and assumptions. Require all proposed design options to demonstrate performance against the KPIs.
	Establish a hierarchy of approaches: super energy efficient building envelope (design and materials), building services (technologies and controls), and renewable energy (generation, storage, control). This will produce compounding savings upstream.
	Simplify systems and components, valuing passive solutions over active solutions wherever possible
	Think beyond current benefit:cost evaluations and minimum performance standards. Incorporate whole-of-life, total cost of ownership, and non-monetary value evaluations
	Create enhanced value by ensuring each part, subsystem or system provides multiple benefits.
	Optimise energy systems to meet the diverse annual and seasonal conditions (use and generation), and implement control strategies to minimise or shift peak demand and optimise self-consumption
	Incorporate technologies (e.g. integrated BMS, EMS) and processes (e.g. post occupancy evaluation) to inform design success and future designs.

2.5 What comes next

The Studio reports will be shared with the client. QUT has had some expressions of interest from other consultants who are eager to participate in further integrated design studios in the future.