The Innovation Hub

for Affordable Heating and Cooling

Final Sub-Project Knowledge Sharing report

IDS-06 Transport Buildings (Stations) (UoM)

Project IDS-06_v2.0

27th May 2022

The University of Melbourne

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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Primary Project Partner

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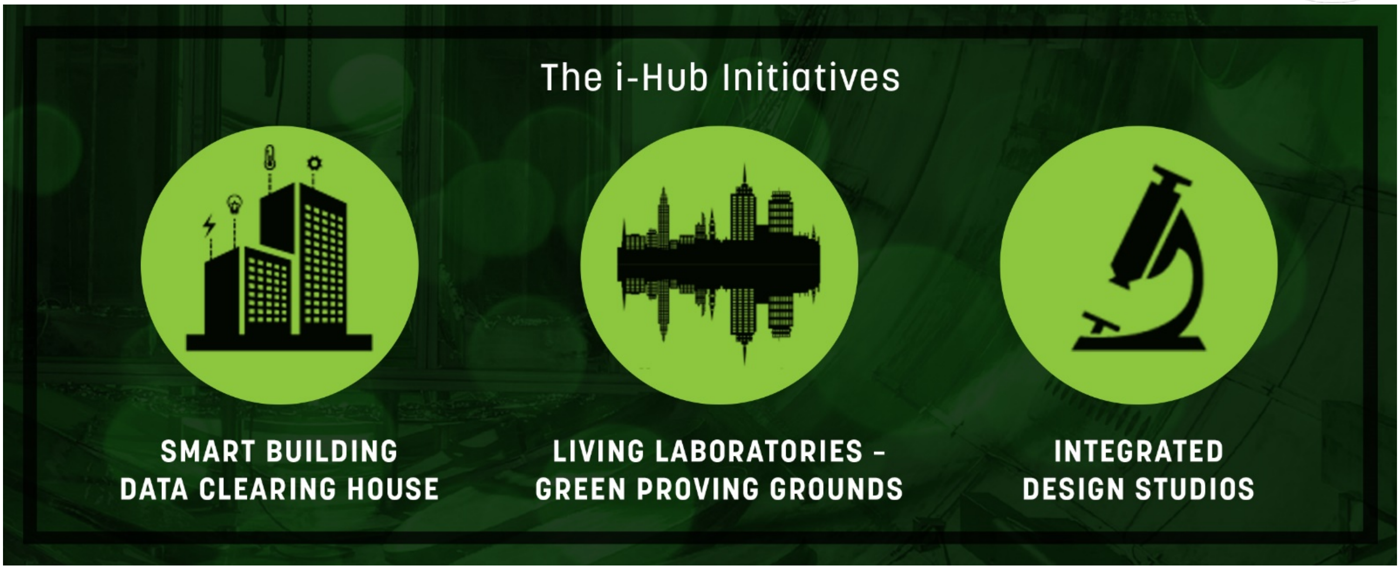

Final Sub-Project Knowledge Sharing Report

This report is produced at the completion of each IDS sub-project and captures the breadth of activities and information produced in the sub-project including studio logistics. It makes use of cross referencing the individual reports produced in each sub-project rather than repeating information wholesale.

The 'i-Hub IDS-03 Design Studio outcomes report_100%_inc_Appendices' is intended to be the main technical learnings and outcomes report of interest to industry when shared publicly.

Lead organisation	The University of Melbourne		
Sub-Project number	IDS-06		
Sub-Project commencement date	1st July 2021	Completion date	27th May 2022
Report date	27th May 2022		
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IMPORTANT NOTE regarding reading of report:
The integrated design studios are repeating format studios conducting research on two levels:

1) Integrated Design: Each studio builds upon previous studios to explore how best to facilitate integrated design between architects and engineers. Research and lessons learned are cumulative across studios.
2) Zero Carbon Research: Each studio explores zero carbon design measures that are relevant to the building typology featuring in that studio. Research and lessons are specific to the building typology used in the studio.

To improve readability (for readers reading multiple reports), material that has been repeated from 'Knowledge sharing Reports' from previous IDSs such as common background, repeating cumulative research, or learnings, has been delineated and identified as such by showing on a greyed-out background.

1. Sub-Project overview, objectives and importance to market/industry

The overall objective of the integrated design studio activity is to examine how integrated design occurs on case study projects with outcomes on two fronts:

Enabling of Integrated Design

Significant cultural barriers exist in the design of sustainable buildings in relation to achieving the high technical performance required in tandem with the architectural building amenity desired. The root cause of many of these barriers is the relationship of the engineering and architectural disciplines in the design environment. The integrated design studio programme has been designed to study how to best overcome these barriers.

Much has been written on how to achieve integrated design and yet its realisation in practice is often ad-hoc or poorly executed. The integrated design studio programme tests best practice integrated design methodologies in a working design environment. The methodologies trialled are refined through subsequent design studios.

The 'i-Hub IDS-KS Catalyst for Integrated Design' document provides the most up to date iteration of the integrated design methodology to be trialled in the IDSs (refer Section 4 for more detail).

The focus of the studios is on mobilising both engineering and architectural input into the conceptual ideation stages of project formation. Renewable energy and zero carbon are used as target outcomes. Concentrating on this key stage in the design of projects creates maximum downstream impact.

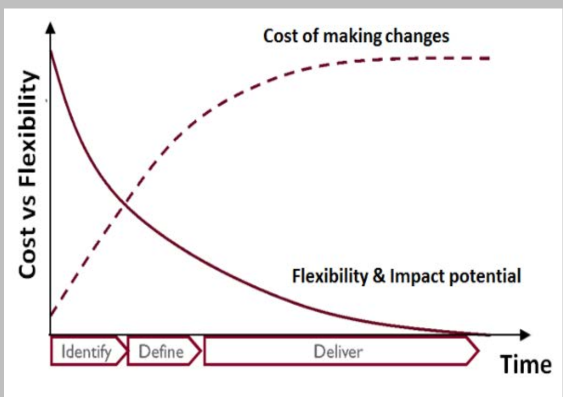

Figure 1: Decision value: Opportunity with time.

Building Typology Research

The studios use case study projects as a part of creating a design environment in which to test integrated design. As a result, the studios also provide an opportunity for building specific research into potential integrated solutions.

The primary focus of the building specific research was net zero carbon outcomes. Net Zero design sits at the nexus of architecture and engineering and also fits well with AIRAH interests in affordable HVAC that reduces energy use and environmental impact, and ARENAs agenda of renewable energy. Each building typology examined (nine in total over fourteen different studios), contributes to a useful, albeit necessarily incomplete, wider picture of net zero design across the building industry.

The case study building typology used for IDS-06 Transport Buildings (Stations). Transport buildings operate in particularly demanding public environments. Issues of public realm and security means many of the functions are required 24/7 and during periods when staff are not occupying the buildings. As a result, energy consumption can be twice that of other public buildings. They are also usually fully integrated into the planning of the infrastructure networks they service and have evolved to hubs for commerce, retail and recreation often making the projects important focal points for local or regional regeneration. Their design as a result differs from most buildings in that the lead roles are more usually filled by engineers than architects. This arrangement makes them particularly interesting in gaining insight into relations between the architects and engineers from different perspectives to deliver great design outcomes. IDS-06 used two new 'lock' train stations as planned for Edithvale and Chelsea level crossing removal projects in the Frankston train line as a case study.

The learnings from each of the integrated design studio sub-projects get collected and consolidated across the full program of IDSs in a separate 'knowledge sharing' sub-project IDS-KS.

Figure 2: Example Student Design for Chelsea Station, Zhaonan (Harlan) Guo, Sizhe (Mason) Mo.

The key partner organisations involved in IDS-06 were:

Fiona McLean (Client Representative) – Fiona is an experienced architect having worked in the briefing and design of large projects both in Australia and overseas. These include large commercial facilities and rail infrastructure. Fiona was assisted in this role by senior personnel at Cox Architects (refer below).

WSP – WSP are a large multi-national engineering company who are currently working on the LXRP (Level crossings removal project) in Victoria designing a number of stations. WSP provided engineering and sustainability advice.

Cox Architects – Cox are a large architectural firm well versed in public architecture and similar to WSP are currently responsible for the delivery of a number of LXRP station projects in Victoria.

The University of Melbourne – Academics from both the Melbourne School of Design (MSD), and the Melbourne School Engineering of with a mix of 12 Masters of Architecture and Masters of Engineering students, supported by a part time research assistant.

AIRAH – The Australian Institute of Refrigeration, Air Conditioning and Heating.

Studio work for IDS-06 was initiated July 2021 with semester work running for 15 weeks. Technical feasibility vetting of the design ideas produced throughout the studio (by the consultants) took place over 4-6 weeks in the period after completion of the semester work.

Outcomes for industry include practical insight into how to enable integrated design in practice, along with design ideas and assessments of the potential for renewables and other zero carbon enabling initiatives in railway station building design.

Figure 3 Example Student Design for Chelsea Station, Aurelia Tasha Handoko, Chhay Kourng (William) Lay, Olivia Loh, Charles Yan Pan Ng.

2. Challenges experienced and how these were overcome

Challenges in the delivery of the studios were experienced on two main fronts:

1) Logistical delivery of the studios. Logistics issues related to the delivery of the studios themselves and were related to aspects such as the time required to elicit signing of agreements with the sub-project partners, and COVID-19 impacts such as the need to instigate remote delivery and limitations on the number of engineering students that were able to be enlisted. The final impact of these factors was felt to be minimal or able to be managed. The Lessons Learnt Report produced for the studio refers (details provided in Section 4).
2) Level of integrated design able to be achieved. Trialling of the best practice integrated design methodology formulated (from current literature) in the studio exposed many limitations and over-simplifications that impacted design integration. This was the reason for undertaking the studios in the first place and these challenges resulted in learnings that were then incorporated into the integrated design models for subsequent studios. As above refer to the Lessons Learnt Report produced for the studio for detail (details provided in Section 4), and the 'Catalyst for Integrated Design' document produced summarising the practical learnings on how to encourage integrated design on projects.

3. Summary of lessons learnt and Evaluation of the Sub-Project impact and technology

Valuable learnings occurred in both objective areas of the studios, on how to implement integrated design in industry, and also on evaluation of potential technology solutions appropriate to the building typology used as a case study. Headline summary learnings are provided below:

Integrated Design Process

Note: learnings in relation to the integrated design process were formed across all IDS conducted so far (01 to 05 & 07) and hence this section of learnings contains repeats from other IDSs. Learnings relate to the practical implementation of integrated design principles from literature (for example the setting of high level goals, establishing right culture etc., refer to the Catalyst for Integrated design document for more detail).

- Integrated design requires a 'design co-author' mindset in all participant designers.
- Integrated design ideation happens in a limited time window after designers reach a level of base understanding of the disciplines to be integrated.
- Integrated design benefits from active third-party curation.
- There is a high level of excitement and buy in to the concept of integrated design meaning simply articulating this as a project goal achieves some gains.
- Integrated Design Process - one size does not fit all.
- Establishing Integrated Design extremes (or discipline goal posts) helps.
- Precedent disparities exist in the working frameworks architects and engineers bring to projects.
- Experience levels of designers is an important consideration in integrated design.
- Architects and engineers have different preferences in communicating and engaging. Visual communication is the best universal language and is useful both for communication and as an analysis/collaborative thinking tool.
- Base level of understanding required in disciplines to be integrated before integration can happen effectively.
- An informed process of interrogation and iteration can assist in the process of integration.
- Face-Face interaction is an important factor in facilitating integrated design.
- Easily accessible software tools for interrogating technical performance is important to early design/integration process.

- Visual communication is the best universal language and is useful both for communication and as an analysis/collaborative thinking tool.
- An informed process of interrogation and iteration can assist in the process of integration
- Time pressures on delivery often negatively impact integration.
- An integrated design team is most effective in a comfortable space, encouraging innovation and experimentation, built on strong social connections.
- Materiality is a nexus of integration, drawing together architecture, structure/ construction, and sustainability.

Net Zero Carbon design of transport buildings (stations)

A select number of 2 group projects (Group 1 – 'Edithvale Exchange' and Group 4 'Uplifting Chelsea') were assessed further to verify feasibility of the initiatives proposed to achieve net zero carbon. It is noted that the examples investigated are both located in Melbourne with a predominant mild temperate climate, requiring heating in winter and cooling in summer.

The scope of the students' propositions largely related to material selection for structures with large spans, high-floor-to-ceiling heights and a mix of uses ranging from the train platforms all the way to different retail and transport related functions. In that sense, students frequently had to consider the nexus between functional requirements, aesthetics, structural systems, and energy performance.

Timber was a natural choice for embodied carbon reduction, yet fire safety regulation made its use unfeasible. Energy efficiency, (wastewater) management and carbon reduction, were some of the key concerns investigated by students to see if a zero-carbon target was achievable for these types of facilities. Solar simulation software (such as Ladybug) was used by the groups to conduct shading and sunlight-hour studies. In addition, the more advanced eQuest and EnergyPlus applications assisted with building envelope optimisation, in particular: shading, thermal insulation, skylight area definition and more.

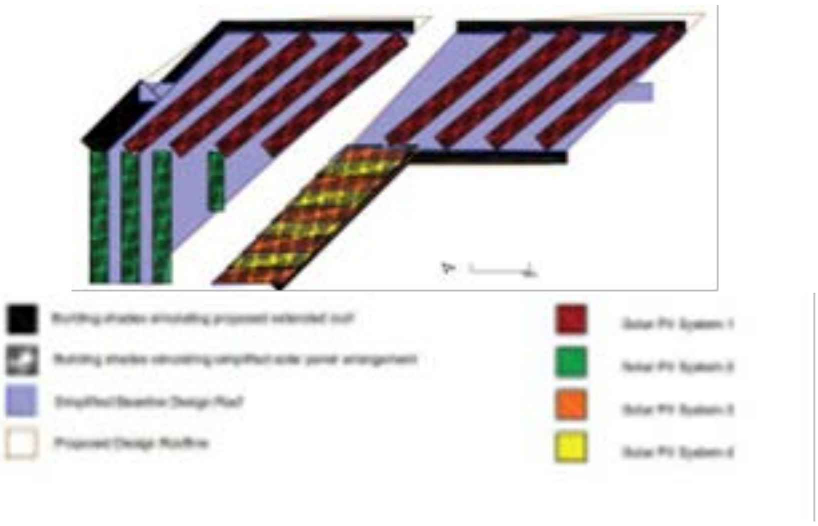

Figure 4: Simplified roof layout for eQuest simulation

Within each IDS project, there were many common active and passive sustainability initiatives applied, however each group achieved slightly different and innovative ways to incorporate this into their designs.

Passive Measures

Some of the initiatives introduced by the students were progressive or innovative and provided some new ways of thinking about and designing transport facilities.

- Optimising material choices
- Rainwater drainage & Collection
- Applying reused and recycled materials
- Optimising façade performance and roof orientation with horizontal extrusions for shading
- Extensive planting/natural vegetation for shading and as thermal buffer

Active Measures

Next to addressing passive measures, a number of active measures were proposed by the two groups selected from this studio. Large roof areas of the stations with up to 2500 m^2 of surface area did provide opportunity for students to investigate the use of photovoltaics, next to other active measures such as ground coupled heat pumps, wind farming, and Piezo-electricity generation.

Key initiatives can be summarised as follows:

- Photovoltaics (rooftop)
- Ground coupled heat pump for cooling and heating
- Wind harvesting
- Piezo-electricity generation
- Battery Systems

The feasibility vetting of designs produced for two case study stations (Chelsea and Edithvale), found that the schemes developed by students resulted in credible solutions using market-ready technologies for the design stations.
Several initiatives assisted in the reduction of operational energy demand: Increasing heat-pump efficiency via smart temperature settings, changing from gas-fired to electric HVAC systems for heating and cooling, the replacement of conventional station lighting with low energy LED lighting, as well as an automated lighting control strategy linked to actual use via internet of things (IoT) technology. Via these initiatives, and assuming that only about 55% of the roof area covered enclosed spaces, the student feasibility vetting showed a 29% reduction compared to Business as Usual (BAU) in operational energy demand could be achieved. For this high energy intensive train-station typology this a significant percentage.

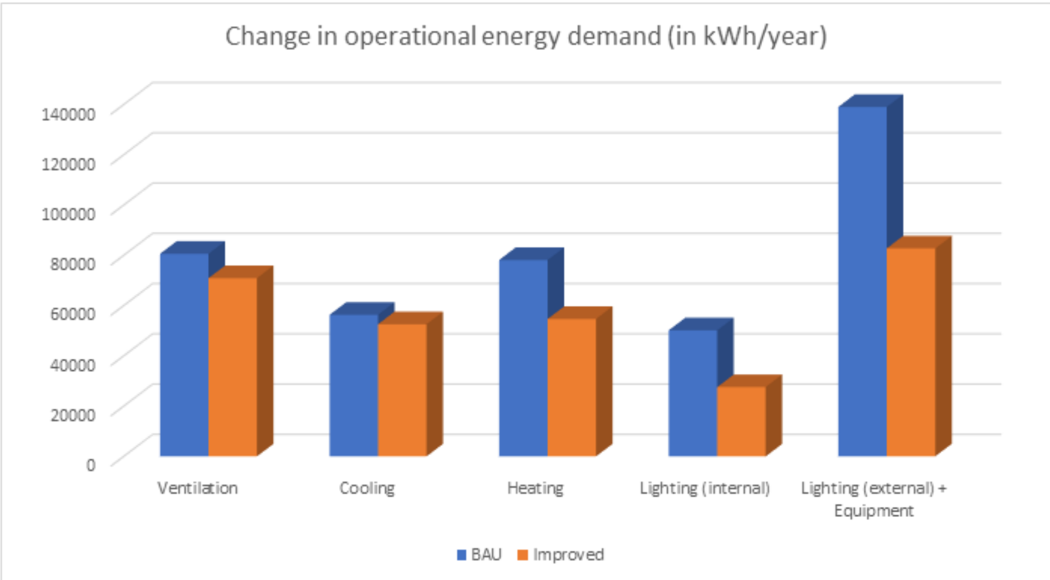

Figure 5: Project Vetting – Operational Energy Demand Reduction Strategies

In addition to the above reduction in operational energy demand, other opportunities were investigated to provide additional onsite generation. Several options were investigated, such as wind farms, Piezo-electricity generation, and photovoltaic (PV) cells. Existing efforts around the world1,2 highlight in particular the benefits of solar rooftop (or other) PV cells. For the student project vetting, the large roof areas of the stations with up to 2500m2 of surface area did provide a major opportunity to investigate the use of photovoltaics in conjunction with battery usage. Analysis of the roof shape and orientation resulted in the proposition of four different solar array subsystems with panels tilted at 30 degrees of each orientation. Approximately 1200m2 of rooftop area could be covered by the PV cells, whilst still allowing natural daylight to penetrate the building via south-facing glazing in the roof. Combined, these subsystems have a capacity to provide 243,800 kWh/a of energy supply, thereby offering approximately 60% of energy supply when compared to BAU.

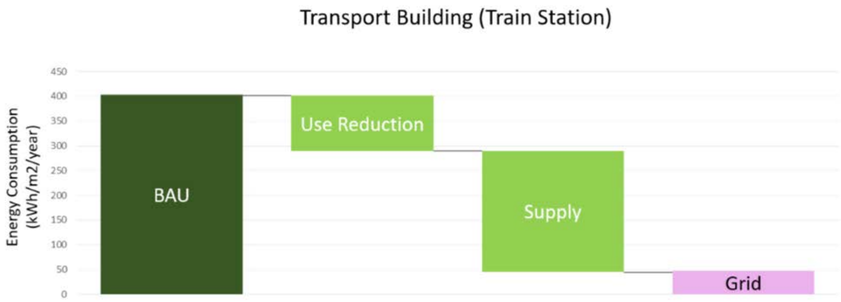

Figure 6: Operational reductions and Generation reductions in grid demand

Based on the analysis of the technologies investigated by students for their design of a train station, zero carbon solutions for this highly energy intensive building typology were not achieved, yet students found credible pathways towards significant energy reductions while implementing a holistic response to environmental, functional, and aesthetic concerns, achieving a total of approximately 89% reduction in grid energy consumption when considering energy demand reduction (29%) and 60% on-site renewable supply of energy when compared to Business as Usual.

The project highlighted materials as an essential consideration in reducing carbon. Emerging concerns around the mercury (Hg) levels in fly ash used to replace cement present a potential threat to its continued use. The whole sustainability industry would benefit from further research in this area. As a large educated client often instigating project and network wide specifications organisations like PTV and LXRP are in a good position to assist in undertaking work on this front.

Sub-Project Impact (linked to studio planned objectives)

Overcome discipline prioritisation and risk-management barriers that prevent design consultants from providing innovative designs for their clients: IDS-06 continued to provide lessons on this front. Stations are unique in that they are highly functional in nature and also act important community nodes needing to marry into the surrounding urban environs. The value of integrated design (beyond just net zero), in considering the breadth of required function and respect to the surrounding area be it activation of retail, or through respect of local residences was evident trough the discussions that were had and the design outcomes that resulted.

Contribute to the knowledge and development of the IDS process being developed and facilitated by i-Hub: Valuable contribution to development of the integrated design process as per above commentary.

The potential contribution of innovations to increasing the fraction of building energy that can be economically provided by on-site renewable energy (target 25% increase relative to BAU) is assessed: Energy savings strategies (through both improved efficiency and on-site generation) delivering up to approximately 90% reductions in grid demand for the case study stations examined when compared with business as usual (BAU).

Maximise the local use of on-site renewable energy: This result was due to the large platform (and potential roof) areas involved in stations as well as their low-rise nature. Note that the energy use of the rail operations was excluded from these calculations.

Findings from this sub-project will progressively feed into the establishment of a 'Carbon Catalogue' where the IDS team will consolidate benchmarks related to different technologies in the context of a range of different project types. In return, this will inform the 'Knowledge Sharing' aspect of this initiative, as each sub-project will have an impact on the wider IDS program.

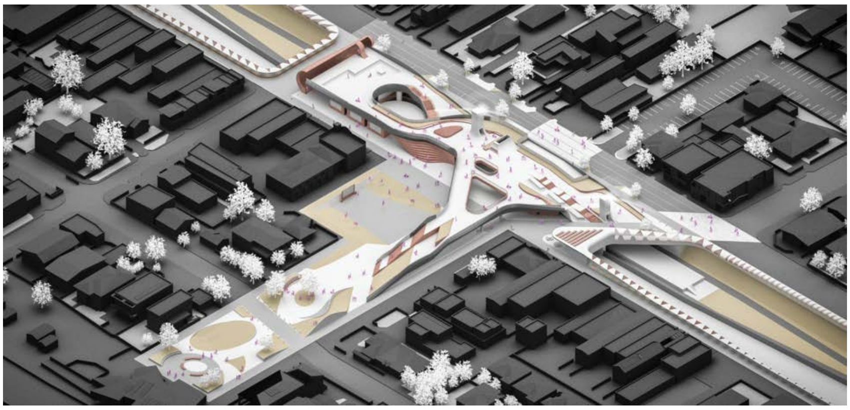

Figure 7: Example student design Edithvale station, Zhe Li, Fangyi Miao, Qi Zhang.

4. Links to reports

The following reports were produced for public sharing as a part of or in relation to IDS-06 and the wider IDS activity stream. Click on documents to be linked to publicly available copy.

IDS-06 Specific Reports

- **i-Hub IDS-06 Design Studio outcomes report 100% inc Appendices**: Main technical learning/outcomes knowledge sharing report. Includes selected student work, consultant feasibility vetting report etc.
- **i-Hub IDS-06 Lessons Learnt Report :** Details of lessons learnt (Technical and logistical).
- **i-Hub IDS-06 Final Sub-Project Knowledge Sharing Report :** This report.

Related material of interest produced in wider IDS activity

- **IDS-KS JP01-CREATING INTEGRATED DESIGN IN AN ACADEMIC ENVIRONMENT: PROCESS AND A METHOD** : Journal paper manuscript – note: not accessible publicly until published due to Journal IP restrictions. Link available on request once published.
- **IDS-KS JP02- IDS: An integrated design approach for architect/engineer education using Zero Carbon targets** : Journal paper manuscript – note: not accessible publicly until published due to Journal IP restrictions. Link available on request once published.
- **IDS-KS JP03- Lessons from Integrated Design Studios focusing on Zero Carbon** : Journal paper manuscript – note: not accessible publicly until published due to Journal IP restrictions. Link available on request once published.
- **IDS-KS MA01 What are we doing about integrated design:** PDF of published article in Ecolibrium August Issue.
- **IDS-KS MA02 Building Performance Attributes:** Article content (pending publishing).
- **IDS-KS MA03 Urge to Merge** PDF of published article in Ecolibrium May 2020 issue.
- **IDS-KS MA04 Interesting Tension** PDF of published article in Ecolibrium Jun-July 2021 issue.
- **IDS-KS i-hub summit recordings** : Recordings of the four integrated design webinars (I-IV), undertaken over the course of the IDS activity stream.

- .**IDS-KS Integrated design Symposium** : Recordings of the symposium that took place over three days October 25-27th 2021.
- **"Architects and Engineers Declare" Integrated Design Symposium** panel participation held December 2021.
- **I-Hub Outcomes Symposium:** 17th May 2021 (note: link to symposium flyer, full transcription still to be uploaded)

5. Applicability beyond current contract.

The sub-project outcomes are envisaged to have the following applicability beyond the current contract:

- Catalyst for Integrated Design document: Envisaged this will be able to be used by industry in setting up integrated design environments. Note that the current version has already been requested by and provided to individuals in industry.
- Studio Outcomes Report: these are envisaged to be referred to by people in the industry working with the case study building typologies in question, and also by the wider design fraternity looking at where to start on net zero design in these typologies.
- Papers and magazine articles produced will join the literature surrounding integrated design able to be interrogated into the future.
- Carbon Catalogue: Results from the project vetting will feed into a *Carbon Catalogue* per Building type that draws on the benchmarking undertaken by the IDS team.
- Consultation with Industry: Members of the IDS team will follow discuss results of the investigation with industry representatives about applicability of findings from the IDS on wider use in practice.
- Ongoing programme of integrated design studios (IDSs). It is envisaged that the IDSs will continue in an unfunded form in each of the three institutions involved in the project (The University of Melbourne, The University of Wollongong, and Queensland University of Technology).

6. CONCLUSIONS

Conclusions and integration into the wider IDS programme

The IDS framework, paired with experienced educational experts, and equally proficient engineering and architecture consultants, supported student designers to challenge the existing dogma of (often sequential) design collaboration. Via the integrated design approach, multiple environmentally optimised, and architecturally challenging proposals were developed by students over the course of the semester. The studio progress was logged by the IDS team via detailed observations. The observations reflect some of the conditions met by professionals in everyday practice, but they also offer ample suggestions for process-improvement, change in attitude, and suggestions on how to set up integrated design processes to maximise the output of all involved.

The output generated by the students represents an array of solutions, that address the functional and operational requirements of the client, whilst challenging existing conventions. Inspired by the consultants and the studio tutors, the students include and test a range of innovative technologies. The engineering consultants take some key solutions further and produce an investigation about the renewable energy applications and energy performance of the building type studied with comparative studies on zero Carbon interventions vs BAU. These will be compiled and cross compared in final reporting.

Summary of Building Typology Zero Carbon Design Learnings

The large platform areas and low-rise nature of stations and their ancillary/related buildings means that there is a large opportunity for on-site generation through photovoltaics. Opportunities also exist in integrating photovoltaics into platform canopies providing sun protection, and also in the right orientation, noise amelioration (to surrounding public areas).

Reductions in grid demand of up to 90% were identified (30% through energy demand reduction and 60% through on-site generation) when compared to business as usual (BAU).

Material choices were identified as an important consideration given the restrictions in use on potentially flammable materials such as timber in rail environments. The significant industry influence large infrastructure clients have in setting project and network wide specifications was noted as potentially useful if work on materials like ‘green concrete’ were to be rolled out.

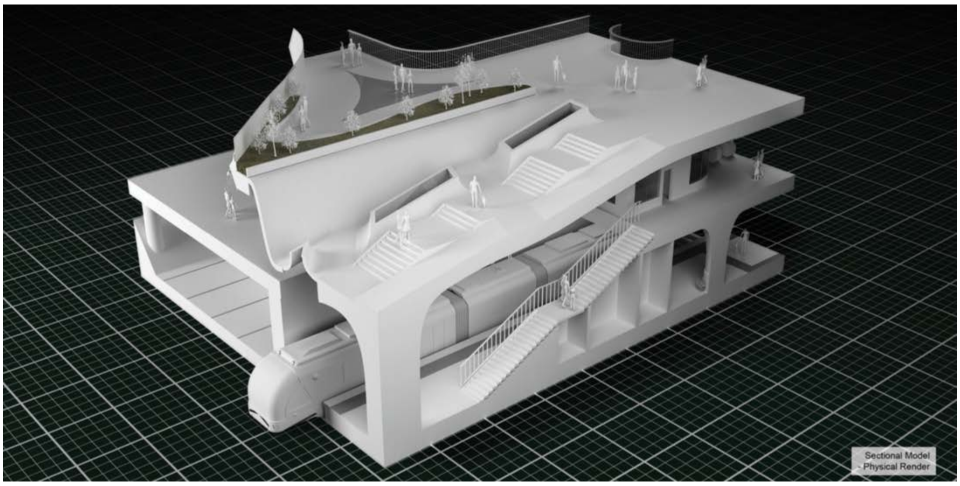

Figure 8: Example student designer work – sectional modelling Edithvale station, Zhe Li, Fangyi Miao, Qi Zhang.