The Innovation Hub

for Affordable Heating and Cooling

Design Studio Outcomes Report (100% Milestone)

IDS-08 CSIRO Laboratories

Project IDS08

27 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.
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.

Primary Project Partner

i-Hub Design Studio Outcomes Report (100% Milestone)

The IDS-08 CSIRO Laboratories Integrated Design Studio investigates design innovation to reduce net energy consumption through use of renewables and other energy technologies. Over a 14-week period, a group of architecture and engineering students work jointly with Engineering experts to develop a laboratory facility. This type of facility is known to have high operational energy requirements.

Based on a project brief presented by the client, students explore novel approaches to develop a CSIRO Laboratory facility within the wider Melbourne area. Particular focus is given to the intrinsic nature of the layout of such centres and their environmental affordances, by integrating novel technologies that provide synergies with various programmatic requirements, functional considerations, and overall aesthetics, thereby significantly reducing its carbon footprint.

Lead organisation	The University of Melbourne		
Sub-Project number	IDS-08		
Sub-Project commencement date	21st July 2021	Completion date	27th May 2022
Report date	27 May 2022		
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1. SUMMARY

1.1 Purpose

This report summarises all findings taken from IDS-08 and marks the 100% completion milestone at the end of the project. Information inherent to this report will flow directly into the 'Lessons Learned' from IDS-08 and they will be further disseminated under the IDS Knowledge Sharing strategy associated to the program.

1.2 Executive summary

The IDS-08 CSIRO Laboratories was initiated late July 2021, after substantial stakeholder engagement with client representatives back in Q2 of 2020. In line with the approach taken for the IDS run the semester before, it was intended for this IDS to be run entirely as a face-to-race class on the Melbourne University campus. The IDS steering committee therefore searched to secure participation of Architecture and Engineering students, who could now interact in person with each other and the participating industry consultants throughout the duration of the semester (experience on prior IDS showed that this setup is the best option for collaboration). The focus on face-to-face teaching led to difficulties in securing the participation of the desired number of Engineering students, as many are currently offshore due to the pandemic. In addition, changes to access to the university campus due to continued lockdown restrictions from week 2 of semester, have affected the plan to teach face-to-face. Teaching had to resume entirely online for the remainder of the semester (yet too late to still enable the IDS steering committee to introduce more Engineering students to the IDS cohort).

Each of the 9 students (comprising 8 architecture and 1 engineering student) have been asked to work in one group but advance their ideas individually. Group activity has revolved around environmental research and exploration of sustainable technologies, whilst individual architects concurrently undertake design exploration exercises and the development of initial design proposals. This concurrency of design focus has catapulted students into integrated design thinking from the first week. The architecture students and the engineering student have interacted with the student tutor twice a week, and with the industry consultants, on at least a weekly basis. A dedicated 'Catalyst for Integrated Design' guideline underpins the collaborative effort and helps in the joint development of common goals toward 'Net Zero' design. The two weekly studio sessions are being held online this semester, allowing the team of UoM academics to diligently observe and analyse the integrated design process as it unfolds.

Observations of the integrated design effort point towards preliminary lessons learned, which include (but are not limited to):

- Important to establish a level playing field from which each participant can benefit.
- Clear articulation of common goals as a key priority, and in this IDS translating into clear assessment criteria and being upheld in an intelligible way through the integrated design development process.
- Reminding participants of how the common goal translates at progressive design moments has been approached in this IDS through the hands-on guidance of the studio tutor and industry consultants to maintain designers' focus as they navigate an unfamiliar design process.
- Important to bring multiple perspectives into focus, via collaboration and critiquing, as designs develop.
- Articulation of a 'whole of project' vision is an important part of engaging other contributors in an integrated design proposition.
- Cross-disciplinary engagement can occur intuitively/unconsciously within the same (student) cohort; engineer/architect dialogue was more easily aligned using graphics; articulating the engineering component of a return brief engages the engineering disciplines with the project.
- This IDS demonstrated that managing collaboration is not always easy especially with only one engineering student; collaboration across disciplines is upheld if the engineer/s is/are fully engaged in the process.

Further work on the Integrated Design Studios will occur during the remaining 1-2 weeks of the semester and the majority of the findings are expected to emerge once students complete work, solutions are vetted and in-depth interviews with project participants have been carried out (in the 4-6 weeks after studio submissions have taken place).

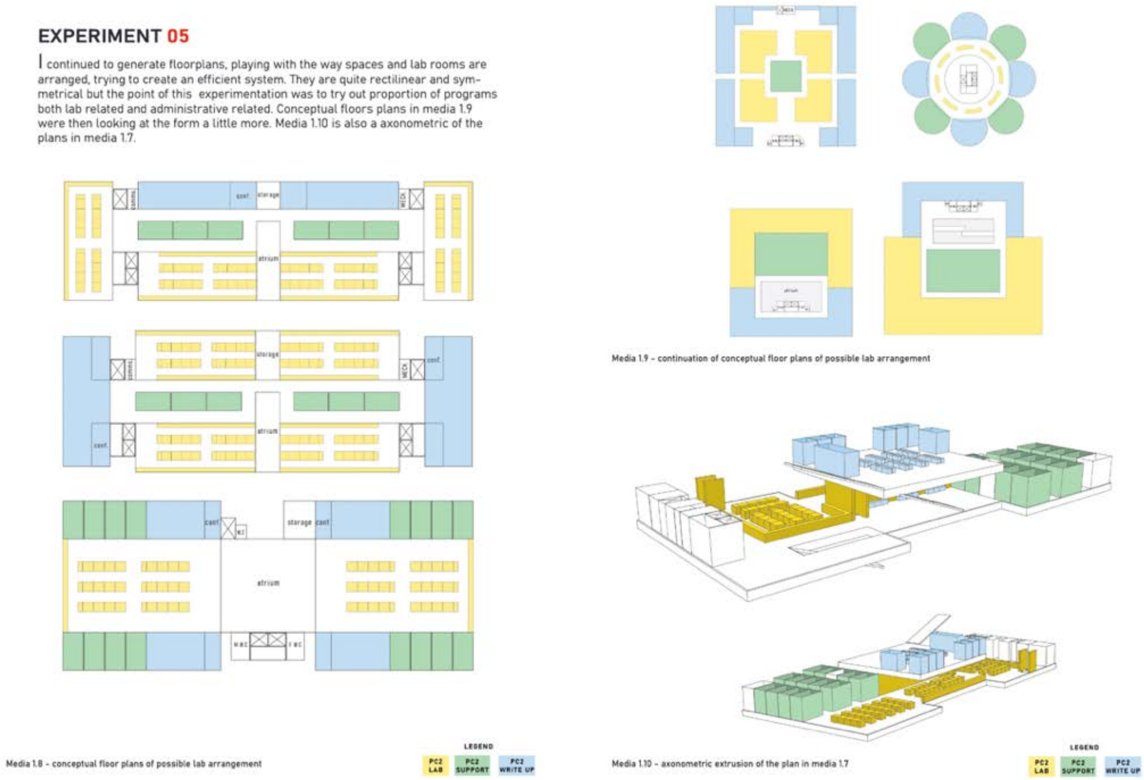

Figure 1: Emma Lee – laboratory plan exploration

2. PROJECT CONTEXT AND INCEPTION

2.1 Context to the CSIRO Laboratories - Integrated Design Studio

In the lead-up to University of Melbourne’s start of semester, Prof Brendon McNiven from the Faculty of Architecture, Building and Planning, and Prof Lu Aye from the Melbourne School of Engineering had engaged in intensive industry consultation in order to search for compelling case-studies to investigate new technologies under the Integrated Design Studio banner. This IDS project ran during Semester 2 2021, which span over 13-15 weeks from late July until mid November.

The CSIRO Laboratories project embodies a programmatic and functional specificity that promises a fertile testing ground for design exploration, particularly when considering Zero Carbon constraints. The CSIRO’s 2020 sustainability strategy has set a firm goal of reaching Net Zero by 2030 through significant emissions reduction together with addressing energy demand and supply. In focusing their attention on energy intense laboratory buildings, the CSIRO client is looking for a hypothetical mixed-use laboratory building of 3 – 4 stories providing roughly 50:50 office: lab and designed to be sustainable and sufficiently agile for optimising operations and energy performance. The hypothetical building should ideally embody sustainable principles that can be applied to other locations and explore new innovations, including ideas with associated risk.

In the weeks leading up to the start of semester, the Melbourne University team went on to gain University of Melbourne internal *Ethics Approval*, select the Design Studio tutor, establish the context for the IDS to integrate seamlessly with the existing curriculum, and chose the industry consultants to join in on the project.

2.2 Studio Inception

Several kick-off workshops took place at the start of Semester 2, to introduce all studio participants to the IDS principles, as well as providing a platform for stakeholders to get to know each other. Due to the COVID-19 context, these workshops predominantly occurred online. It was decided to split the initial workshops over several classes in early August (during the first two weeks of semester). The workshop sessions included presentations from the IDS research team, University of Melbourne academics, the clients, and the participating consultants.

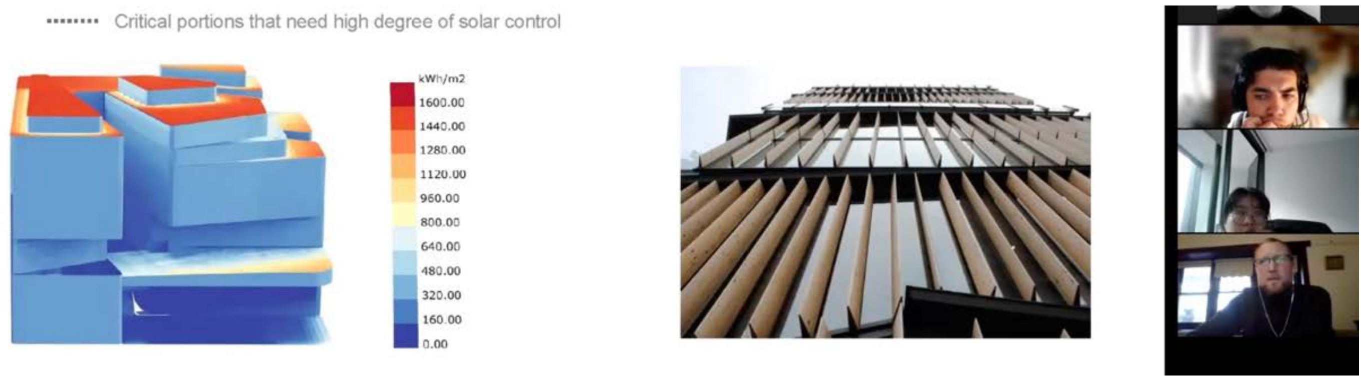

Figure 2: Sustainability consultant presentation - zoom snapshot

Next to the benefits for information exchange, the initial kick-off workshops also fulfilled the essential task to introduce all key IDS participants to each other and facilitate social bonding, particularly between architecture and engineering students.

Figure 3: Briefing session – Zoom 'online meeting tool' snapshot

2.3 Client Engagement

This Integrated Design Studio (IDS) is working with an open-minded client, whose aim is to redefine the design of a CSIRO Laboratory facility in the context of the new CSIRO 2020 sustainability strategy which has set a firm goal of reaching net Zero Carbon by 2030. The CSIRO strategy includes new buildings as key contributors to reaching the 2030 zero carbon goal through sustained minimal environmental impact over a 50-year lifespan but also through creating opportunities to minimise energy demand via optimised operations in more agile buildings. In the client 's words, "The less energy we use the better" and to that end the client welcomes opportunities to test unprecedented and novel technologies, brought into context with innovative design ideas for a laboratory project that enables trialling of innovations and engaging more with the community. The IDS-08 CSIRO Laboratories project is joined by industry experts and consultants, with a proven track record in the design, delivery, and operation of these bespoke assets. This mix between willingness to experiment, paired with a high degree of expertise in laboratory design, is greatly benefitting the conversations and design approaches in the studio. The client has been involved intermittently over the first half of the semester, providing guidance and feedback, particularly at mid-semester and the projected end-of semester milestone.

2.4 Site Visit

A greenfield site at the east end of the CSIRO Clayton 'campus' was chosen by the client for this project. The site is surrounded by native vegetation and to the east of the existing CSIRO facility buildings, The CSIRO campus lies immediately north of Monash University's main Clayton campus so, sitting on the edge of a large research and education precinct. Due to COVID-19 restrictions, it was not possible for IDS participants to physically visit the site. The absence of a site visit would, in normal circumstances, place significant constraints on the design process. However, due to the prominent location of the site close to Monash University, a body of information is publicly available about the site and surrounds. Photographic images of the site (40 – 50) together with aerial images were provided to students and, apart from vegetation at the perimeter, the site is relatively flat and clear - an ideal hypothetical site for a hypothetical building.

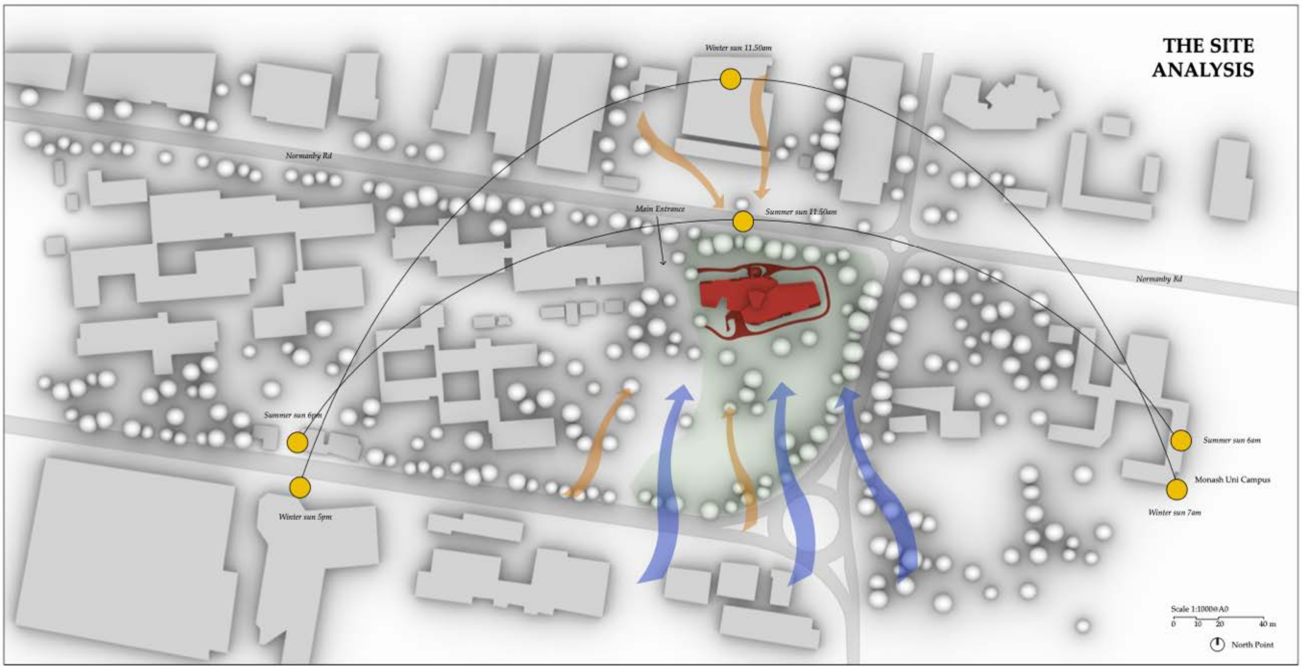

Figure 4: Vincent Yuan – site analysis – mid-semester

Figure 5: Simran Kaur – site context – mid-semester

3. DESIGN STUDIO PROGRESSION

3.1 Setup for Collaborative Design Integration

In order to provide guidance for the programming of Design Studio activities, and in particular their interface with the investigation on integrated design, the IDS management updated their detailed manual titled: *'Catalyst for Integrated Design'.* Released approximately 2 weeks before the studio's commencement, it combines aspects of design collaboration that cut across architecture and engineering disciplines, and it ties directly into the studio-teaching process. The manual first addresses overarching aspects of design integration to then delve into the specifics of environmental building performance, human comfort, and mechanical design systems. The manual ultimately assisted the studio tutor to coincide their activities for advancing design concepts with key milestones for addressing and integrating technologies throughout the semester.

General

Understand the **limitations of traditional**, non-integrated design (solutions).

- Facilitate an environment that prioritises working on **common goals** over **individual goals**
- Establish **trust** among participants (open/non-judgmental/sensitized/willing/etc)
- Allow every participant to understand what's **important to the others**.
- Explain the **process** each participant (group) typically goes through, in order to derive their desired **output**.
- Understand **why** we often see things **different**ly, and
- develop a **common language** that cuts across discipline silos (metaphors/analogies/co-experience)
- Call students '**designers**' **rather than architects** and **engineers**. Engineering should empower architecture and vice versa
- Set **common targets** à instill a sense of joint ownership … and
- introduce a sense of **shared responsibility** across group participants
- **Knowing in action/heuristics**: discuss and advance integrated design solutions on the fly…
- **start with** educated guesses/**rule of thumb**, **then verify** validity of assumptions for preferred solutions

Focus on Performative design

- Address **environmental** building **performance** systemically across Arch and Eng
- Establish joint environmental **targets** per relevant building type à apply end-use performance metrics
  - o What are the mechanisms to address them in **early**-stage design?
  - o What are the mechanisms to address them in the **advanced** design stages?
- Develop an iterative Arch/Eng process for **optimising performance** (Optioneering)
- Search for integrated design responses to human **comfort** and environmental **loads** à understand how various aspects of the Arch and Eng design are connected.
- Search for **synergies** via design **innovation rather than** relying only on **mechanical** solutions (passive over active) … as part of that…
- foster **multi-functional design** – design elements in an integrated design should be doing more than one thing at once (at least 3 things).
- **Define** the **characteristics** that represent the '**integratedness**' of a design solution. That's what the success of this project should (also) be measured against!

3.2 Schedule for Interdisciplinary Engagement

The studio tutor proposed a broad IDS schedule in week two of the semester, based on his experience as an integrated design studio leader within a 13-15-week semester, as well as preparatory conversations held with the industry consultants, the CSIRO client, and the academic participants. The schedule addresses the output requirements typically inherent to Masters-level design Studio teaching at the Melbourne School of Design, and the specific IDS output requirements for exploring novel technologies to support a Net Zero Carbon design goal in a hypothetical laboratory building. In particular, the schedule mapped out the intensity and duration of engagement between the architecture students, engineering students, the regular architectural and engineering design consultants and guest consultants. Within this framework the studio leader allowed for a degree of adaptability in response to the unique circumstances for this IDS being entirely online and operating with slightly reduced student participation.

3.3 Weekly interaction between Design Studio Participants

After the initial online kick-off workshops, the CSIRO IDS moved into the period of bi-weekly 3-hour design review sessions.

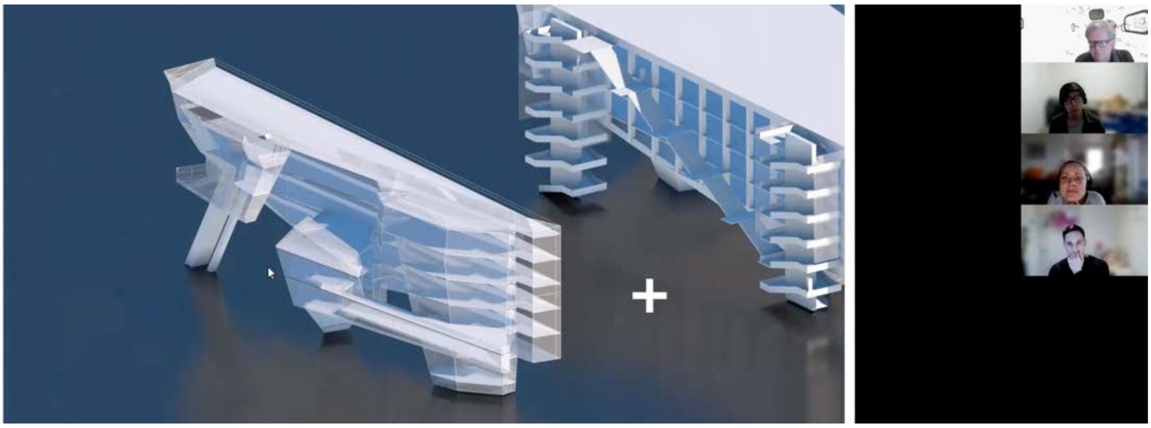

Figure 6: Zoom collaborative session – students, client and consultants

The CSIRO Laboratories IDS has modified the familiar group approach to studio interaction to better assist engineering integration from the single engineering student, and more readily respond to students' individual progress towards an innovative 'Net Zero Carbon' outcome. The first half of the semester focused on demonstrating a range of integrated design strategies (climate responsive design, zero carbon brief, design performance) giving context to guide studio interaction and align with the significant individual design challenge presented by the studio leader. The initial three weeks was marked by additional presentations by the CSIRO client and the Sustainable Design Consultant together with presentations from the CSIRO architectural consultancy's laboratory specialist team. Each student was concurrently preparing first preliminary responses to the site context and absorbing the learnings from the consultant presentations into the articulation/visualisation of the various programmatic features they had previously researched. This was undertaken in the context of two extreme design responses – one architectural and one engineering. This became the framework within which students would evolve their ideas up to mid-semester and led activity into translating the brief into what it means for the design of this complex building typology, with particular focus on its environmental affordances.

In a 13-15-week design programme much of the front end is taken up with briefing and bringing design parties up to speed with each other's discipline (in general knowledge terms), the back end is conversely dominated by design development and documentation type activities.

A first public presentation of preliminary design concepts occurred at the IDS Mid-semester presentations in mid-September.

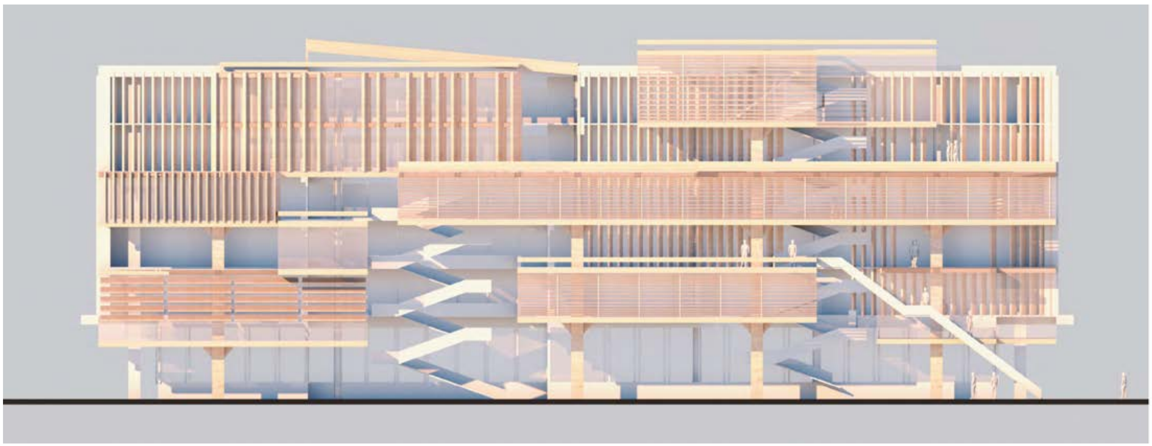

Figure 7: Zirui Murphy – preliminary design exploration

4. PRELIMINARY FINDINGS

4.1 Understanding Professional Specificity (and how to overcome it)

Striking a balance between architecture and engineering requires active curation. The CSIRO IDS asked designers to work individually, in the sense that each would be responsible for all key deliverables. Earlier IDSs have taken different approaches but, whichever path students follow towards integrated outcomes, the goal is to enable students to think beyond disciplinary boundaries, reached through mutual respect and understanding that flourishes in a collaborative environment.

Earlier IDSs had found that designers gained significant benefit from working in groups by offering opportunities for architects and engineers to work closely together to encourage collaboration. In this IDS the preferred group approach was adapted in response to the lower numbers of students, including one engineer, working in an entirely online environment. It has been observed that working as one, albeit slight larger, group continues to offer good opportunities for interaction with the single engineer. The engineer readily took on a peer-to-peer role collaborating with all architects, gaining familiarity with their different approaches. It is encouraging to observe early opportunities for peer-to-peer critiquing that are expected to play out further as the semester progresses. A mutual respect did emerge in these peer-to-peer sessions, with the architects seeming to respond well to the engineer's guidance and feedback. It was observed that via the process of weekly student presentations, all students had opportunities to reach a level of familiarity with different design thinking during the first half of semester as well as an appreciation of what the engineer can bring to the table.

The limited opportunities for social bonding between students in this online IDS has impacted the sense of co-ownership across disciplines that in previous ID's had broken down barriers. It is difficult to discern through observation whether students did feel that they were part of one group. Students have welcomed opportunities provided by the studio leader to spend zoom time together without staff during some studio sessions; it is understood that students were able to fully engage the engineering student in group discussions. A key aspect of this studio is that each student has been supported by a continuously high level of engagement from the industry consultants as they each experience the challenge of integrative thinking.

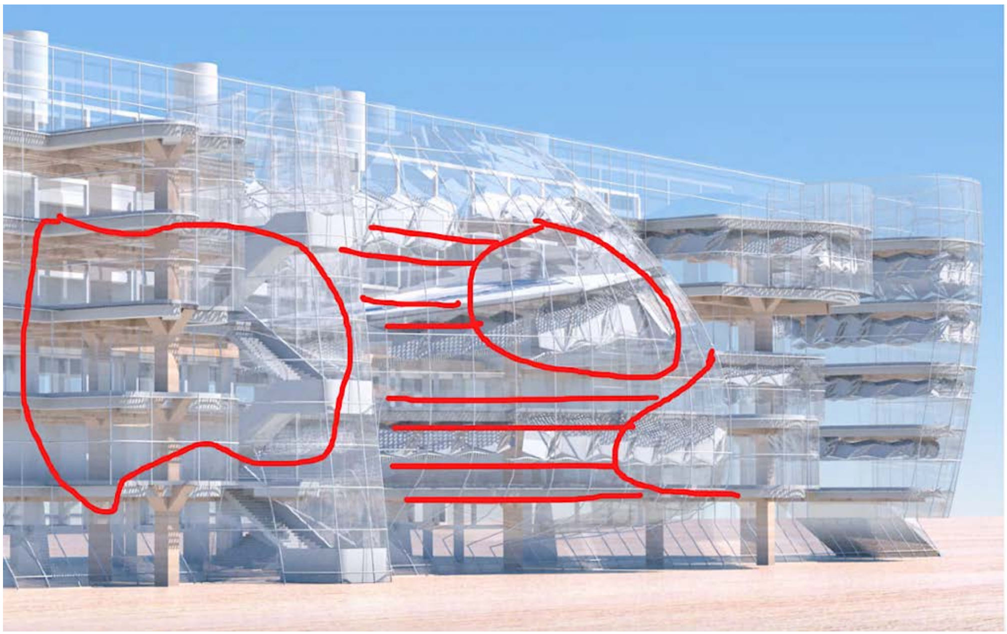

Figure 8: Zirui Murphy – live zoom feedback – balancing architecture and engineering

4.2 Aligning the Dialogue

Integrated design is the coming together of multiple disciplines to produce design solutions that meet 'whole of project' visions. Early observations in previous Integrated Design Studios (IDSs) were that not all designers are used to working in this way.

Current design paradigms often place engineering as following architecture in the design process. This encourages a consulting type approach to the engineering where engineers are asked to comment on preformed ideas. Design integration can occur in this model however to a reduced potential with the initial ideation missing ideas founded in engineering aspects of the project.

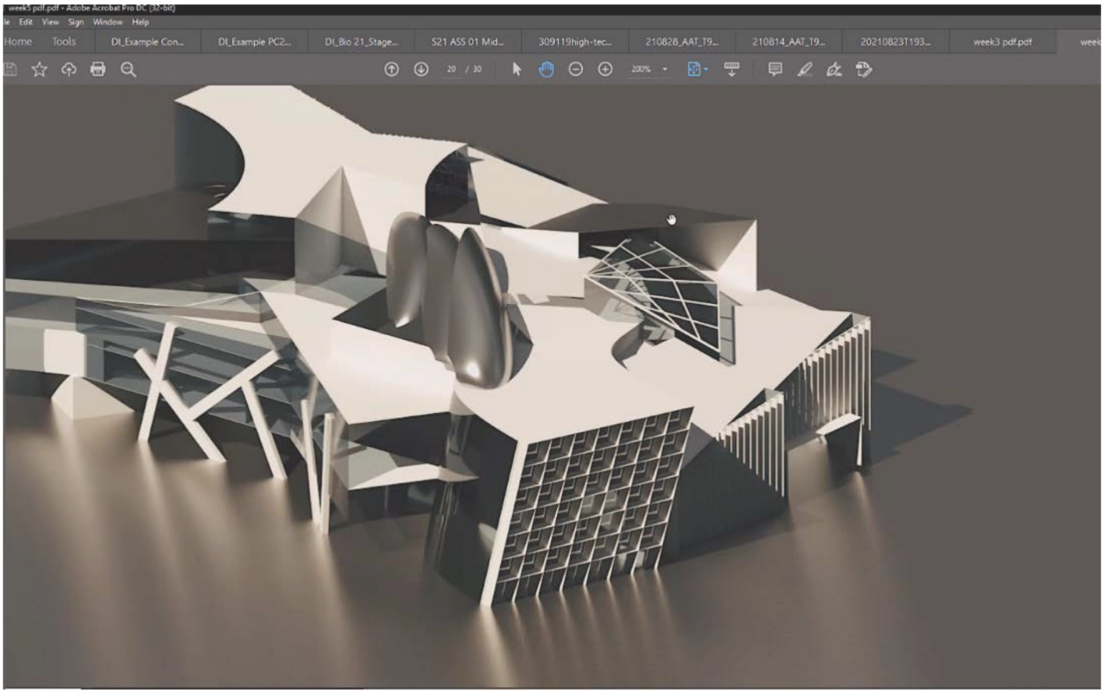

Figure 9: Vincent Yuan – modelling in progress

Early studios found this consulting model difficult to break free from. Attention needs to be paid to create a mindset of 'design co-authorship' in all participants (engineers and architects alike).

Design Co-author mindset: This aspect of design is sensitive to the relationship of individual designers which can be complex. We feel it is an important point to have uncovered however believe it will take some iteration in adjustments of the studio mix and nature of the integrated design process being trialled.

The approach of earlier IDSs to bridging the discipline gap, through encouraging the creation of good working relationships within small groups by both disciplines working together, was found to be a positive move towards alignment of thinking and design co-author mindset. Similar principles have been adopted in this IDS by grouping the smaller number into one group that has, at times, been quite collaborative. Observation of the CSIRO IDS found communication between participants was most lively around shared design goals, particularly environmental design; and the language of the communication in this IDS has been influenced by the engineering student's significant contribution to the engineering/architecture dialogue which took place within the group. This appeared to have multiple benefits such as, no roadblocks to cross-disciplinary communication, no perceived hesitation from architecture students who freely engaged with the engineer and, ready adoption of engineering language. This may suggest that cross-disciplinary engagement occurs intuitively/unconsciously within the same cohort and, engineering/architecture discussion was usually accompanied by illustrations – the language of images crosses all boundaries.

The pathway to co-authorship was less clear. Some architects appeared to embrace ideas from the engineer, who came up with original ideas that could be incorporated into any of the emerging design proposals. Apparent hesitation with adopting some of these ideas may have come from a different struggle, such as the combined challenges of significant project complexity, unfamiliar process, and integrative thinking.

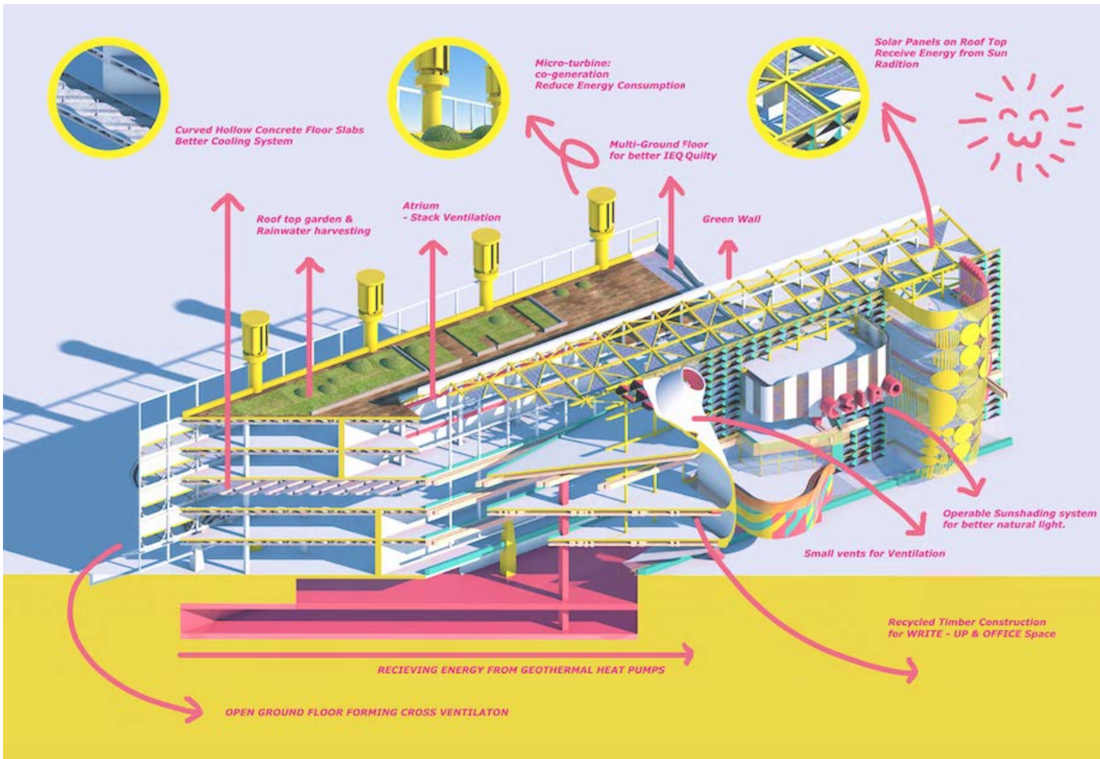

Figure 10: Zirui murphy – integrating sustainability and architecture

Placing this cohort of architects and the engineer into a design space/context with the dual challenge of thinking in an integrated way from the start and communicating amongst themselves, whilst engaging with the industry consultants to help them progress their individual design proposals has, to date, produced some thoughtful mid-semester propositions, whilst others are still in 'slow-burn' mode. Thinking in an integrated way from the start can help students articulate a 'whole of project' vision which, for some students will happen sooner than for others. The whole of project vision offers a context for the contributions of other designers and for co-authors it creates a focus with which they can readily identify.

In the context of this demanding challenge and with each student being responsible for their own design proposal, the provision of more early information around foundational aspects of projects – client, site context / analysis, may have potentially given students a better understanding of the fundamentals of their design propositions and, potentially made it easier to progress individual designs. The CSIRO IDS will continue the same structure through to the end of semester.

4.3 Integrated Design Process

The CSIRO IDS took the approach of demonstrating that good integrated design is a result of where the ideas are generated and presenting all aspects of the design challenge in an integrated way from the start. This included (but was not limited to) integrated design as the new normal, researching multi-function systems, and illustrations of environmental and energy focus leading to new design forms. This challenge, when applied to a complex building typology, has been testing all students to their limit and for each the integrated design pathway has been different.

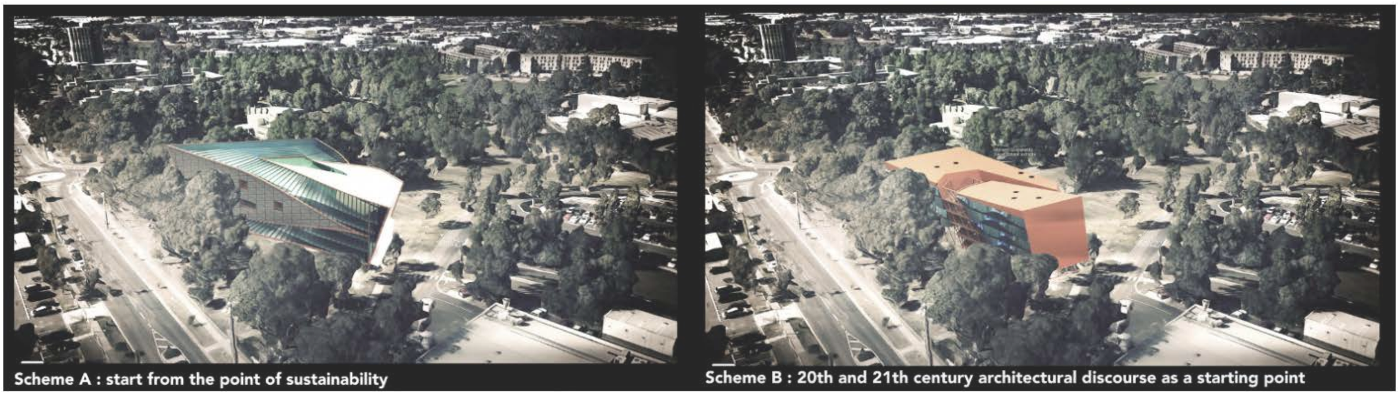

Figure 11: Frank Guo - Vanishing Point - multi-point perspectives

The CSIRO client articulated their expectations from the IDS without prescribing a specific approach or outcome. The adoption of the 'vanishing point' concept as the goal for a new laboratory facility encapsulates the concept of the coming together of multiple perspectives that emerge as a good integrated design outcome that will help define future CSIRO laboratory facilities.

The structure of the studio as one design cohort with an initial requirement to create architectural and engineering extremes as a framework for their ongoing work efforts could be likened to throwing the students in the deep end, albeit with an abundance of life jackets and lifeboats. One engineer is invited to contribute to design authorship of 8 individual projects, and the sharing of tasks and division of work effort usual in developing a group project context has not been possible in the online format. However, the consultants have all maintained a collaborative discourse with students and assisted their analysis of key information. The early introduction of the environmental consultant, Atelier 10, and the laboratory specialist team from DesignInc together with the studio tutor, have provided designers with architectural, programmatic/functional and engineering support throughout the integrated design process.

It was observed early that the engineering student was always willing to contribute to design discussions and appeared comfortable identifying risks and challenges for individual designers in terms of what might work from an engineering perspective. Observations have not revealed how much of the engineer's contributions have been embraced in individual design proposals.

The challenge of producing 'extreme' solutions afforded designers an opportunity to see the impact of optimising engineering aspects over the architecture and vice versa. The need for balance seemed to be readily taken on board by some students along with an understanding of prioritising key design elements as part of the integrated design process. It was notable that all participants readily engaged in the production of extreme architectural and engineering solutions, but it was not always clear how they had arrived at their proposals.

Figure 12: Emma Lee – architecture focus – mid-semester

The frequent design tutorials with the studio tutor and industry consultants have offered fertile ground for multiple perspectives to be considered by students with each design iteration. To date it is unclear how well these different perspectives have been taken on board. Some peer-to-peer critiquing has occurred with the engineering student interrogating designers' work, but more critiques have come from the consultants/studio leader. The ongoing critiquing process appears to have assisted some of the key architectural and engineering priorities to be upheld through each iteration but not consistently for all students. Observation suggests that critiques within a collaborative environment can be very positive.

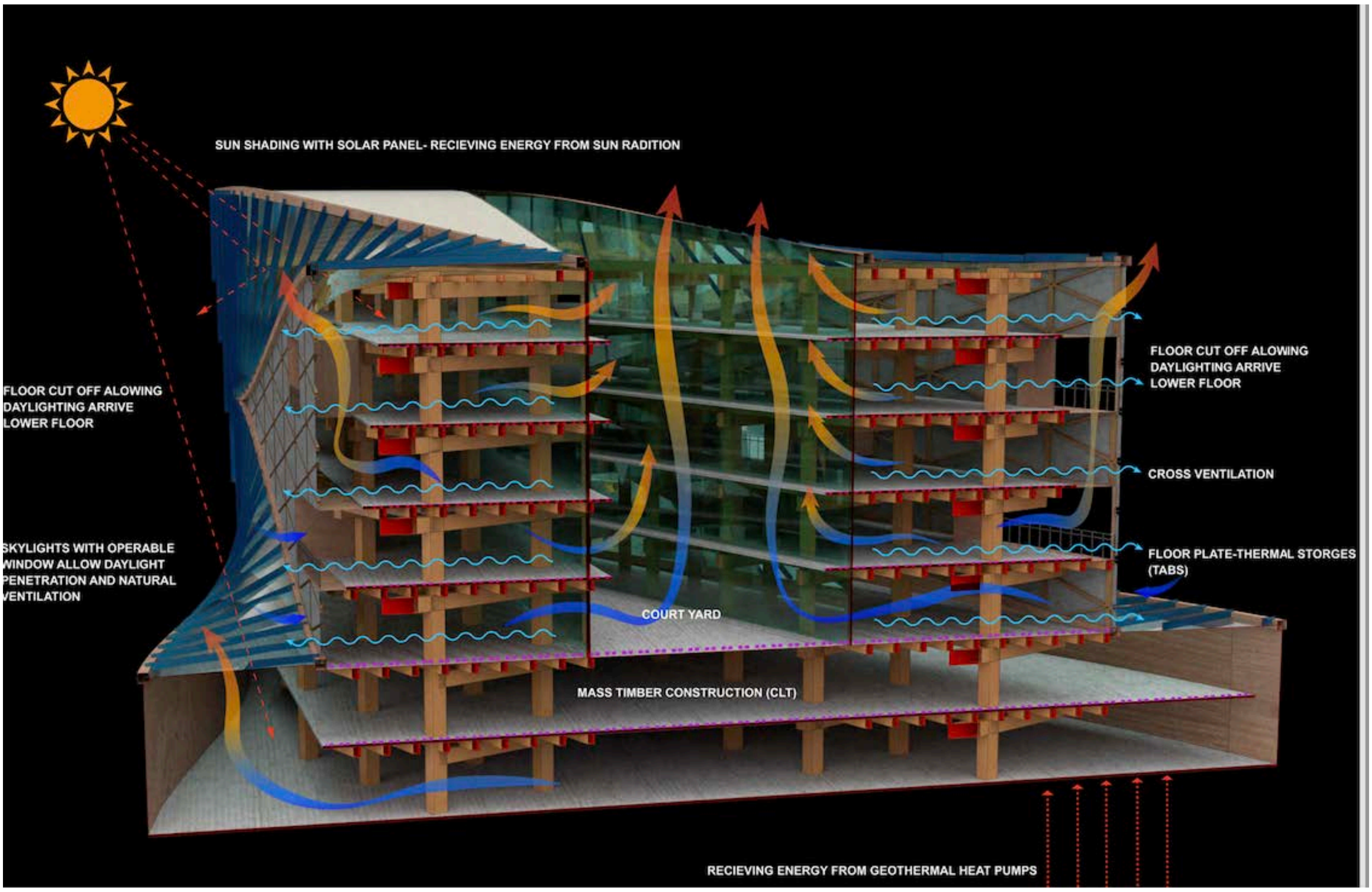

Figure 13: Frank Guo – mid-semester – sustainability focused scheme

As the semester has progressed most designers were conversant with applicable engineering systems and, with varying levels of success, were able to juggle the balance between form and function and have a grasp of the principles they wished to uphold in their final design proposition. However, struggles with prioritising the key aspects of the design that will define a unique outcome remains an ongoing challenge for many. The use of e-tools such as PHPP – Passive House Planning Package energy modelling software introduced by the sustainability consultant, can enhance and underpin designers' understanding of how buildings interact with their environment at multiple levels and that all aspects must work together as an integrated design response. These activities are allowing designers to better understand the relationship between good design and performance, inform their understanding of how buildings work together and broaden their own perspective in a way that will support better integration of design inputs.

Observations have not yet brought clarity to how particulars of the CSIRO brief, such as agile building and optimised operations, have driven early design propositions, nor the return brief. The specialist laboratory consultant presented a detailed breakdown of the brief in the first studio together with sophisticated images to help students' understanding of design interpretations of this complex building typology. It was observed in the first 2 – 3 weeks that students had no sustainability plans or ideas for passive performance of buildings which could be interpreted as students initially not knowing when to answer key questions or how to prioritise between questions when they are all asked at once. It was further observed that students did not necessarily take on board that an integrated design outcome results from alignment of multiple perspectives. The studio leader encouraged students to present their design progress every week to keep them on track and to constantly remind them to think in different ways.

4.4 Working toward Common Goals

One key element being addressed in this IDS, is a targeted articulation of common goals towards Net Zero carbon in the joint architect/engineer effort. Following on from the mid-semester reviews, a team from Atelier 10 has been providing weekly one-on-one engineering feedback in the form of environmental design tutorials, with students able to participate either as individuals or groups. Designers have been guided through the process of modelling and testing their design proposition for its performance against 'Net Zero carbon' parameters. Students will attempt to use the engineers' feedback from these tutorials to inform their individual design iterations with the goal of optimising their own building performance, to more effectively meet the common goal of 'Net Zero carbon'.

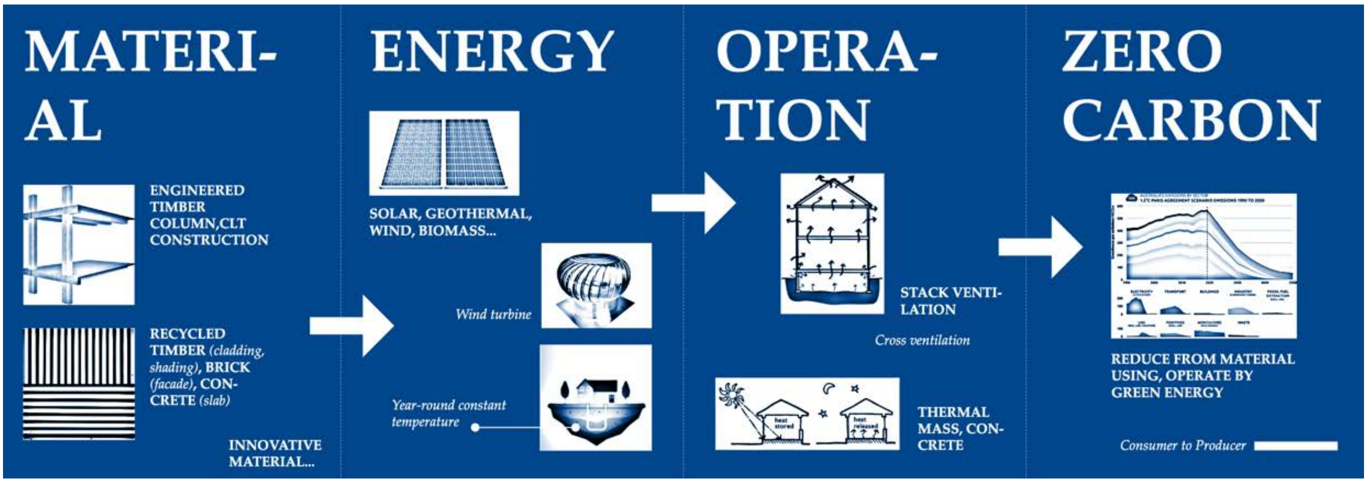

Figure 14: Vincent Yuan – designing for zero carbon

4.5 Feedback from the participating students

All students who attended this class noted that they had come across environmental design in some other classes before starting the IDS. The studio hence was able to draw on prior experience about environmental sustainability by its participants.

Students listed: *in-depth knowledge of technology for collaboration,* as the key design-drivers affecting successful environmental design to achieve renewables/zero carbon goals, followed *Imagination and creativity,* and *the level of existing expertise of individual contributors.*

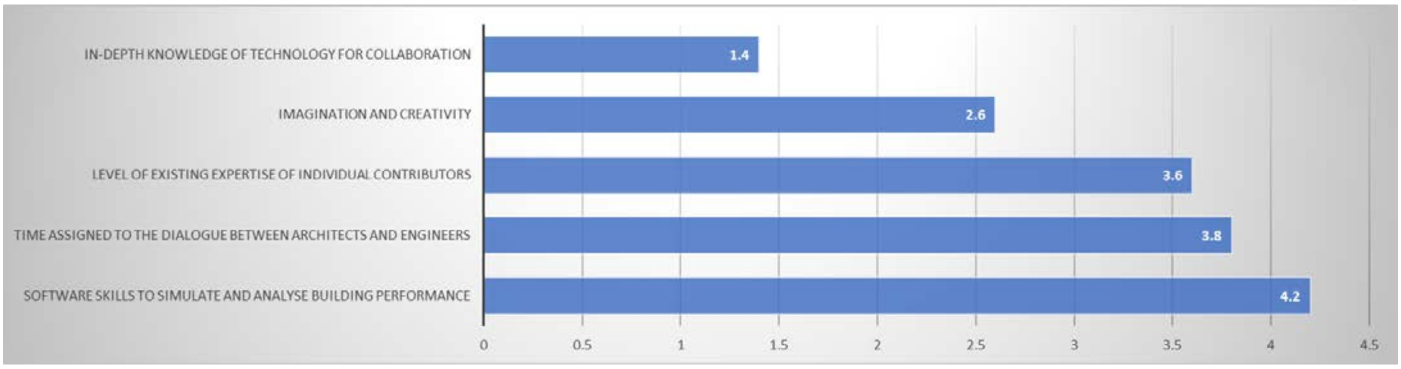

Figure 15: Key design-drivers affecting successful environmental design (with smaller numbers ranking higher)

Overall, the majority of participants felt that the client's brief supported them in achieving a balance between architectural and engineering design, yet some participants struggled with a brief that was still under development and required early integration between architectural and engineering input, resulting in a median score of 4.2 (out of 5). Asked about the impact the brief had, and the way it was written/communicated, most students seemed to appreciate it overall, yet would have preferred more clearly articulated (in writing) goals. One voice was in particular critical suggesting: W*e weren't provided a proper brief or client until around Week 3, which resulted in a rather aimless experimentation phase initially. The area schedule provided to us by Design Inc was very useful to help imagine what spaces were required. Additionally, some of the meetings with CSIRO were helpful although they did come in a lot later in the process.*

Prompted about the most critical decision-making points when balancing architect/engineer input for generating environmentally optimised design solutions, students listed: *discussions about materials*, *the detailed information/numbers about things like how much glass should be on the facade,* as well as *the characteristics of the mechanical systems, and how to incorporate new energy technology.*

As main inspiration from industry consultants for Laboratory design, students listed: *their knowledge about energy usage & materials, the layout/arrangement of building services, and real life expertise from the industry.*

According to the students, the engineers contributed to the authorship of design solutions primarily via *consultancy-type feedback, followed by supplying background data and knowledge,* by offering yes/no check on their design concepts.

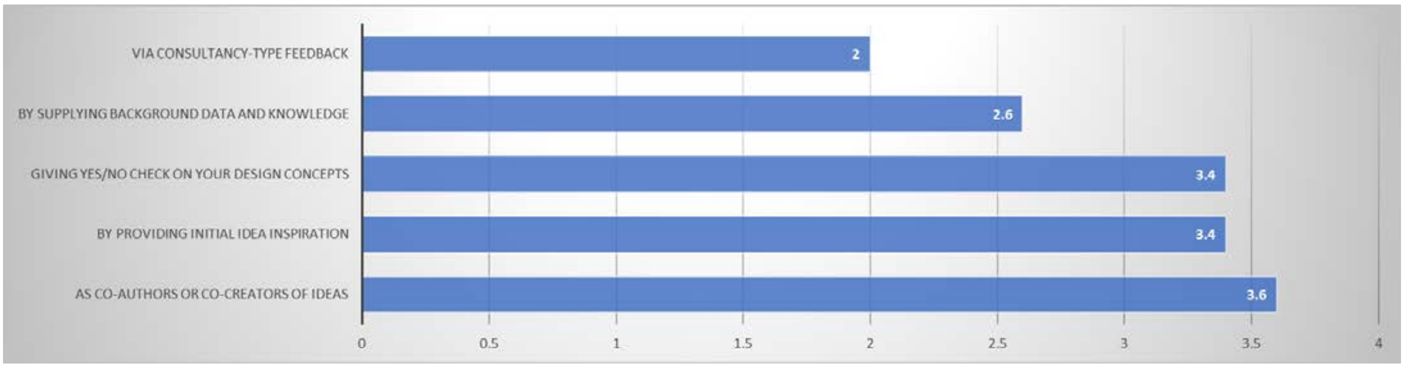

Figure 16: Reflection on input provided by the Engineering Consultants (with smaller numbers ranking higher)

With a median score of 4.2 (out of 5), the vast majority of students argued that the input by consultants strongly increased their 'level of understanding of' environmental issues and associated solutions. Overall, students acknowledged the benefits of the integrated design process, yet some critical voices commented on the timing and extent of input provided: *The tutor should have taken more responsibility on helping us to understand and use the feedback by the consultants*.

For this iteration of the IDS, students lamented the less-than-ideal collaboration between architecture and engineering students, as COVID resulted in a greatly diminished cohort of engineering students. Only 1 such student ultimately joined this IDS. The quality of collaboration was rated 3.2 points out of 5 (with 1 being best and 5 being worst). One student reported: *Unfortunately, there was only one engineering student, so he wasn't able to work in detail with students. As a result, his feedback was quite basic, with passive design and some materiality.* In conjunction with being forced to work remotely due to COVID lockdowns, another student pointed out: *It was really hard to do this class online.* Comments like these point towards the benefits of face-to-face collaboration for such studio contexts.

In IDS-08, a slight majority of students sensed that they had to compromise aesthetics and functional design aspects when balancing architectural and engineering concerns (median score 3.2 - with 2.5 meaning '*neither-nor*'). This points towards some evidence that the performance focus impacted the design aesthetics of project outcomes. One respondent did not feel that way, arguing: *I think it didn't compromise the design, the design is even somehow inspired by the sustainable features.* Another student added: *we could be exploring and utilizing construction system or components as aesthetic or functional parts.*

Despite the overall positive feedback about the IDS, students also reported several challenges when advancing their design-thinking with environmental/engineering constraints in mind, listing: *'knowledge gaps',* followed by *'inability to define joint goals',* and *'contractual / fee barriers'* as key obstacles.

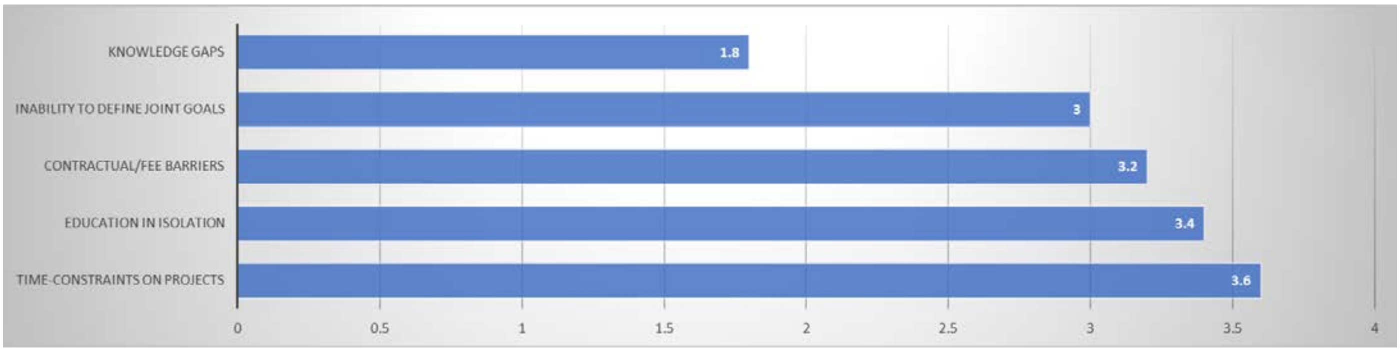

Figure 17: Challenges reported by the students. (with smaller numbers ranking higher)

Additional struggles reported by the students were expressed as follows:

- *trying to balance the needs of both parties.*
- *creating the expressionistic forms that were desired while maintaining the least wastage possible.*
- *balancing between concept, architectural ideas and the environmental and engineering considerations.*
- *not being able to use feedback from one (e.g. an architectural) direction to argue for the other one (e.g. engineering).*

Overall, the introduction to Integrated Design as part of the studio was well received by students with one of them defining it as follows:

- *A very complex task that requires extensive communication between all parties*
- *When both engineering and architecture are intertwined as drivers and considerations from the beginning of the process so they feed into one another resulting in a symbiotic design.*
- *It brings about effective collaboration, ideas from different angles from different professions and minimises the knowledge gaps.*
- *It worth to do on large scale building to be green.*

The question about the usefulness of integrated design processes as part of their university education, elicited a highly positive response, with 80% saying it was 'quite' or 'extremely' useful. Yet one participant highlighting that he/she was not convinced integrated design should be addressed in academia (median score: 3.8 out of 5) stating: *so hard/so real!*

5. STUDIO DESIGN OUTPUT - Select Examples

A select number of 3 student projects (No.126441, 163317, and 187833) have been taken further by the Engineering Consultants (Atelier Ten) in order to consolidate feedback and extract some key data. They also established an Energy Use Breakdown typical for a Lab facility of the size/typology investigated as part of this IDS. Atelier 10 noted that: The scope of students' proposition was mainly focused on passive measures to reduce energy demand and improve the quality of the indoor environment. There was further engagement in upfront embodied carbon based on material and structural selection due to the information presented to the students through the semester. A number of students included space and services for ground source heat pump air conditioning and earth insulation.

The following two sections summarise information contained in Atelier Ten's consolidation/vetting document. The full 21-page document can be found as an appendix to this document.

The scope of the students' proposition has largely related to energy efficiency and carbon reduction, since the Zero Carbon target had been introduced to them as a key part of their brief that they had to investigate. One notable aspect of the student work is the use of a software plugin PHPP (via Rhino/Grasshopper), that allows them to interrogate their 3D designs according to Passive Haus principles.

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

Within the work of these three individuals, four key carbon reduction measures were identified:

- Low Carbon Construction Measures
- Key Passive Measures
- Energy Efficiency and Renewable Energy Technologies, and
- Other Sustainability Initiatives

5.1 Passive Measures

Some of the initiatives introduced by the students were progressive or innovative and provided some new ways of thinking about and designing aged care facilities. All three projects tested their designs within the PHPP interface, in their quest to analyse results and develop optimised solutions parametrically.

- (Atrium) Stack ventilation
- Automated shading devices for laboratory wing
- Operable shading (timber)
- Optimized orientation and form (e.g. Floor depth <15m)
- Heliostat sun tracking system
- Cantilevered horizontal extrusions providing shading

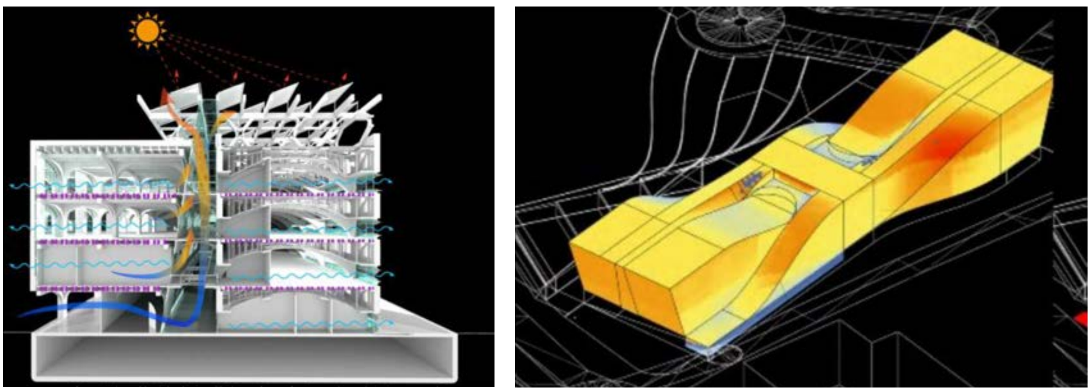

Figure 18: Atrium stack ventilation and radiation analysis on building envelope, Project 126441

5.2 Active Measures

Next to addressing passive measures, a number of active measures were proposed by the three individuals selected from this studio. As an example, projects 126441 and 187833 presented a 'zero carbon loop' with rooftop solar and battery storage, whereas project 163317 used a similar approach, but also added ground source heat pump air-conditioning to reduce the HVAC requirements of the building.

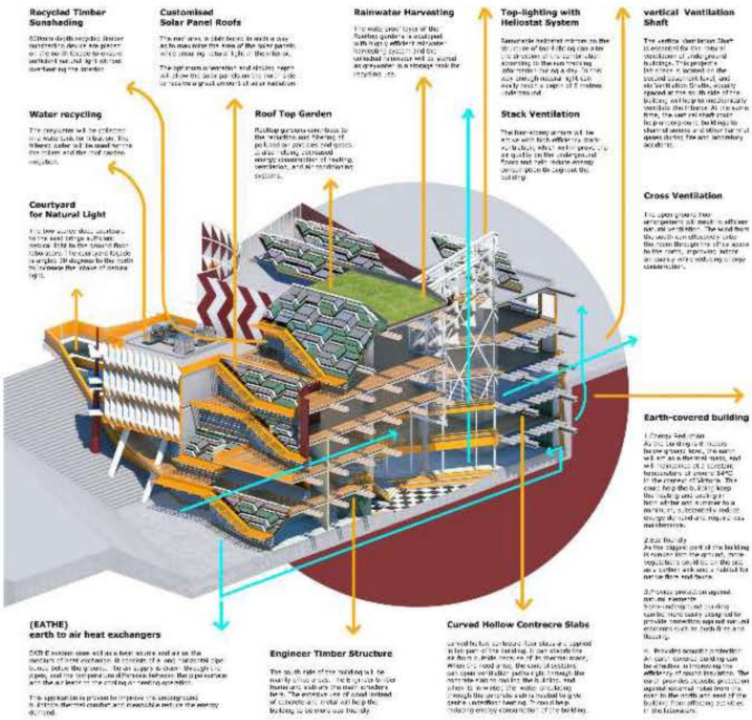

Figure 19: Extracts from submission (Project 163317)

Key initiatives can be summarised as follows:

- Photovoltaics (rooftop)
- Ground source heat pump
- Adaptive and fixed solar PV façade
- Semi-transparent solar PV for roof garden shading
- Battery Systems

Atelier 10 discusses the student results, as well as the scope limitations of the IDS as they state:

All students considered environmental strategies in their designs but validation and documentation of these interventions were very high level. The final schemes demonstrated good integration of sustainability into complicated schemes with stringent functional requirements. However, they lacked the level of detail required for in-depth critique and assessment of environmental performance.

... although the transition from natural gas to all-electric buildings is a critical component of the construction industries path to net-zero, the process loads demands including natural gas for laboratory experimentation have been deemed out of the scope of this vetting study. This could be explored in a detailed analysis of innovations in specific laboratory experimental equipment.

6. SUMMARY OF CONSULTANT VETTING – Performance relative to BAU

Atelier Ten's benchmarking studies found that the schemes developed by students pushed the envelope of what defines a high-performance Laboratory building:

Students were able to show with the use of a high-performance façade, thermal stacking, efficient use of fittings and photovoltaics, that energy savings of around 50% (compared to Business as Usual – BAU) *could be achieved. This is especially significant considering the energy intensive typology which is inherent to laboratory buildings.*

In analysing the possibilities presented by students in their design of a 3-4 storey lab facility, Atelier Ten assess that: *… students have been successful in selecting solutions that are on a credible pathway towards significant energy reductions, achieving a total of approximately 50% reduction in grid energy consumption.*

Regarding the breakdown of carbon reduction measures, Atelier Ten highlight that: c*ompared to business-as-usual, up to 18% energy savings could be achieved through a combination of student strategies; façade optimization, high performing envelope, innovation cooling solutions, and consideration of high performing efficient HVAC services and energy management at the next design stage. This reduced energy demand can further be offset by on-site solar PV to reduce the grid energy demands by another approximately 33% of BAU.*

The embodied carbon of the designs presented by students has also been significantly reduced from BAU, achieving approximately 35% reduction through the design of a timber structural system in the office zones and specification of low carbon concrete for the laboratory structural system and

With all energy reductions for the laboratory typology considered, Atelier 10 nevertheless points out that: *Whilst significant energy reductions were seen across the board when assessing the student proposals, reaching a truly net zero energy design was out of reach. For embodied carbon, further reductions in emissions were limited by the functional requirements of a laboratory, notably the service penetration requirements and vibration limits for laboratory spaces, which influenced the design direction towards post-tension or flat slab concrete solutions.*

A detailed quantitative breakdown of Energy reduction measures can be found in Figure 20.

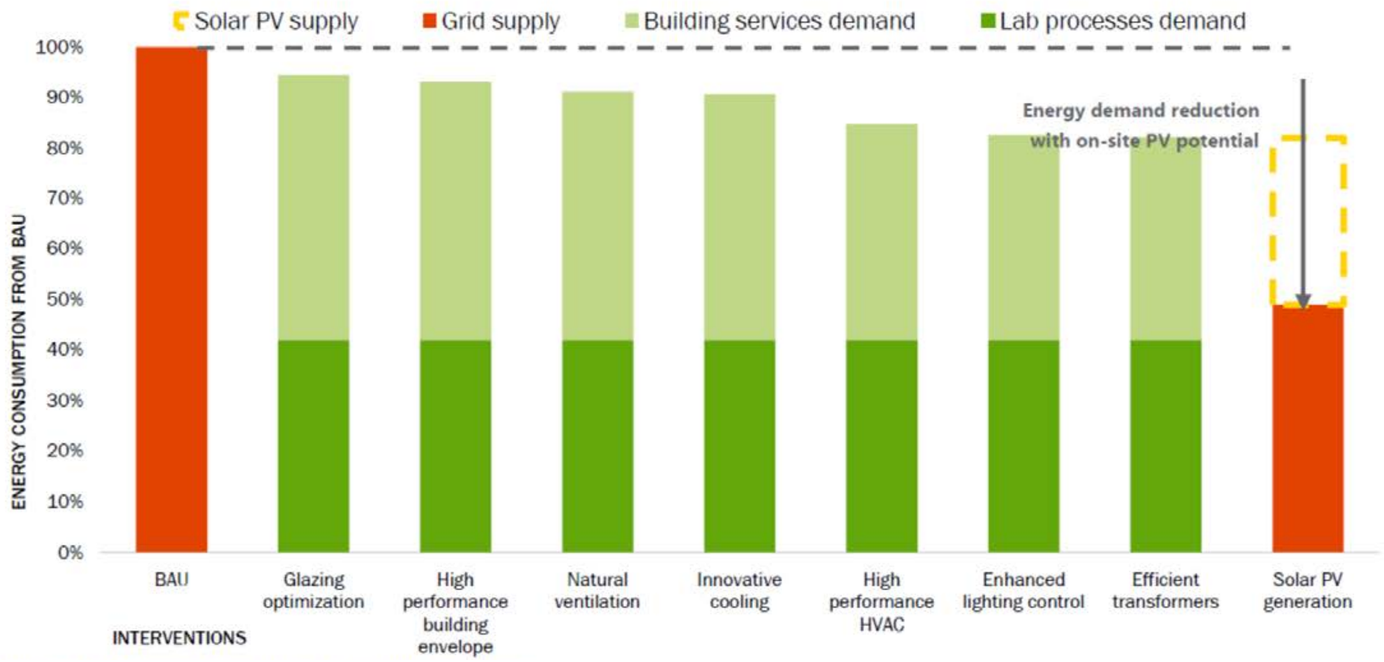

Figure 20: Atelier Ten: Lab Facility – Energy Reduction Strategies

7. CONCLUSIONS

7.1 Conclusions and Next Steps

For the CSIRO lab typology, eight individual projects were being worked on, exploring a wide variety of technologies and innovations to achieve the client's Net Zero carbon goals. Approaches to each design were very different, but it was illuminating to observe that most proposals pushed the boundaries of conventional lab design whilst meeting the functional and operational needs of a reinvigorated CSIRO Laboratory facility. Observations around multiple perspectives, navigating the 'whole of project' context, approaches to collaboration, common goals, and the process of exploring novel technologies and responsive design did emerge. Each project is unique, yet some of the issues faced for design integration cut across all: Questions of shared design authorship, the varying emphasis/benefits of the integrated effort across different ideation phases, the curation of an integrated workflow, and the definition of common goals.

Project participants advanced their designs for 14 weeks until mid-November and consultant feasibility vetting on 3 selected projects occurred thereafter. The engineering consultants confirmed the suitability and achievability of the approaches suggested and in particular saw potential in the thermal optimisation of building envelopes, natural ventilation, innovative cooling solutions, the use of mass timber structural systems for office spaces, the use of low carbon concrete structural systems, and the broad application of solar panels, both on the roof as well as on the facade.

Even if carbon net zero could not be achieved for this typology due to the high and variable energy demand of laboratory equipment (among other factors), a total projected reduction in grid energy consumption of up to 50% compared to BAU still offers significant benefits achieved via zero carbon initiatives and integrated design.

Figure 21: Vincent Yuan – mid-semester sustainability focused scheme

APPENDIX A – Engineering Consultant Vetting Report
APPENDIX B – Student Work